Vegetarian Top Dishes Campaign 2019 – The CO2 impact of meat substitution

Study based on the Dutch "Doe maar lekker vegetarisch" campaign in November 2019.

DATE: 25-11-2019

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Place Gouda, NL

Authors

Freija van Holsteijn	Blonk Consultants
Janjoris van Diepen	Blonk Consultants
Roline Broekema	Blonk Consultants

Blonk Consultants
Gravin Beatrixstraat 34
2805 PJ Gouda

(+31) 0182 579970
www.blonkconsultants.nl
info@blonkconsultants.nl

blonk consultants

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Summary

In 2018 the Dutch National Postcode Lottery, Albert Heijn supermarket chain and Unilever organised the fifth '*Doe Maar Lekker Duurzaam*' campaign. This year the campaign took a step further and focused on vegetarian food, and was therefore renamed, becoming the '*Doe Maar Lekker Vegetarisch*' campaign. The almost three million participants of the National Postcode Lottery received a gift voucher worth €12.50 which they could use in any Albert Heijn supermarket during the period from 28 October to 17 November to buy ingredients for a vegetarian meal for four people.

Replacing meat with a meat substitute or other vegetarian option has a positive climate impact. Blonk Consultants have calculated the reduction in CO_2 emissions resulting from the campaign using the life cycle assessment (LCA) method. LCA is a method for evaluating and quantifying the environmental impact of a product. It covers the whole production chain, from cradle to grave, taking each individual phase of the life cycle into account: the production of raw materials (e.g. chemical fertiliser, electricity and heat), cultivation, processing, distribution, retail, transport, cooking by the consumer and treatment of the packaging waste.

The extra consumption of meat substitutes during the campaign saved a total of 2,752 tonnes CO_2 equivalents. These emissions are equivalent to the emissions of driving 15.7 million kilometres in a car or taking 3,177 flights from Amsterdam to New York.

Contents

1. Introduction

In 2019 the Dutch National Postcode Lottery, Albert Heijn supermarket chain and Unilever organised the sixth '*Doe Maar Lekker …*' campaign. In this campaign the public were encouraged to replace meat with a meat substitute or other vegetarian option. At the end of October all the participants of the National Postcode Lottery received a gift voucher worth €12.50 to exchange for the ingredients to make a meal for four.

Replacing meat with a meat substitute or other vegetarian alternative has a positive climate impact. Blonk Consultants have calculated the reduction in CO_2 emissions resulting from the campaign using the life cycle assessment (LCA) method.

1.1 The campaign

The 2019 campaign was held in weeks 44, 45 and 46 (28 October to 17 November). In these three weeks participants could use their voucher to the value of €12.50 to buy the ingredients for a meal for four. There were also two additional goodwill weeks during which vouchers could still be used, but this was not announced and no campaign materials were on show in the shops during these weeks. The two goodwill weeks were not included in the analysis.

The campaign promoted ten recipes – the ten most popular meals in the Netherlands.[1] For each meal two recipes were provided: one with a meat substitute and one with an alternative vegetarian option, such as lentils or eggs.

Instead of buying products needed for one of the recipes, participants could also use the €12.50 to buy other products included in the campaign ('free shopping'). These products could be chosen from six categories: meat substitutes from the refrigerated section, non-perishable meat substitutes, vegetables, eggs, pulses and vegan desserts. Participants could spend €12.50 on products from these six categories.

1.2 Products in scope

The campaign promoted the ten recipes given in Table 1 below, which lists the original meat ingredient, the meat substitute on offer and the alternative vegetarian option for each recipe.

Table 1. The ten recipes within the scope of the campaign, with the benchmark product, the meat substitute and the alternative vegetarian option as described in the recipe book De Vega Favorieten van Nederland.

No.	Recipe for four people	Benchmark meat product	Meat substitute	Alternative vegetarian option
1	Spaghetti Bolognese with vegetarian mince	Beef mince 200 g	Vegan Magic Mince (The Vegetarian Butcher) 200 g	Lentils 400 g[2]
2	Endive mashed potato (*andijviestampot*) with vegetarian smoked sausage	Smoked sausage (*rookworst*) 250 g	Vegetarian smokey hotdog (The Vegetarian Butcher) 250 g	Chestnut mushrooms 250 g
3	Indonesian stir fried rice (*nasi goreng*) with vegetarian chicken pieces	Chicken pieces 160 g	Vegan Chicken Chunks (The Vegetarian Butcher) 160 g	Unsalted cashew nuts 170 g
4	Vegetable burger and chips	Hamburger 320 g	Vegetarian mc2 Burger (The Vegetarian Butcher) 320 g	Mushroom burger 320 g
5	Vegetarian sausage with baby potatoes and cauliflower	Sausage (*bratwurst*) 320 g	Vegetarian sausage (bratwurst) (The Vegetarian Butcher) 320 g	Vegetable burger 400 g
6	Burritos with vegetarian chicken pieces	Chicken pieces 160 g	Vegan Chicken Chunks (The Vegetarian Butcher)	Chilli beans 400 g

[1] As found in a survey by Knorr.
[2] A 400 g can of lentils contains a drained weight of about 250–260 g.

			160 g	
7	Vegetable lasagne with vegetarian mince	Beef mince 200 g	Vegan Magic Mince (The Vegetarian Butcher) 200 g	Lentils 400 g[2]
8	Indonesian stir fried noodles (*bami goreng*) with vegetarian chicken pieces	Chicken pieces 160 g	Vegan Chicken Chunks (The Vegetarian Butcher) 160 g	Fried eggs 272 g
9	Pumpkin soup with vegetarian meatballs	Meatballs 170 g	Vegetarian mini meatballs (The Vegetarian Butcher) 170 g	Chickpeas 400 g[3]
10	Macaroni with vegetarian meatballs	Meatballs 170 g	Vegetarian mini meatballs (The Vegetarian Butcher) 170 g	Chestnut mushrooms 250 g

These recipes (and amounts in grams) are the basis for the calculation of environmental impact.

Six vegetarian products in a box

Instead of using the voucher to buy the ingredients for one of these recipes, participants could exchange it for a box of six vegetarian products. These six products are listed in Table 2 below. These meat substitutes are also included in the analysis and compared with the 'regular' products containing animal ingredients.

Table 2. The box of vegetarian products and their corresponding benchmark products.

Vegetarian product	Benchmark product with animal ingredients
Unox vegetarian frankfurters (400 g)	Unox frankfurters (*knakworsten*) (400 g)
Unox vegetarian pâté (56 g)	Unox pâté (56 g)
Unox vegetarian tomato soup (570 ml)	Unox tomato soup (570 ml)
Unox vegetarian stew with lentils (390 g)	Unox chicken stew with lentils (390 g)
Unox vegetarian ragout (390 g)	Unox chicken ragout (390 g)
Hellmans vegan mayonnaise (270 ml)	Mayonnaise (270 ml)

Outside the scope of the calculations

The additional sales of all other products promoted in the campaign (such as vegetables and vegan desserts) were not included in the results. This makes it difficult to calculate the reductions in CO_2 emissions because it is not possible to show that these products were bought instead of other products.

[3] A 400 g can of chickpeas contains a drained weight of about 250–260 g.

2. Methodology

The CO_2 emissions of the products were calculated using the life cycle assessment (LCA) method.

2.1 What is LCA?

LCA is a method for evaluating and quantifying the environmental impact of a product or service. It covers the whole production chain, from cradle to grave, taking each individual phase of the life cycle into account: the production of raw materials (e.g. chemical fertiliser, electricity and heat), agricultural production, processing, distribution, retail, transport, use of the product and treatment of the waste. The method can be used to calculate various environmental indicators, such as emissions of greenhouse gases, water use and depletion of fossil resources. The results of an LCA provide insight into the environmental impact of a production/consumption system and can be used to improve that system.

ISO standards 14040 and 14044 (ISO, 2006a, 2006b) are the starting point for the LCA. Functional unit, system boundaries and allocation are key concepts in carrying out an LCA and are explained below.

2.2 Functional unit

The functional unit is a certain amount of functionality that is provided by a product. For food this is primarily the contribution the product makes to providing the nutrients we need. We cannot easily have too much of some nutrients, but for others we have to take care not to eat too much of them (e.g. salt, saturated fats, fat-soluble vitamins).

Important nutrients provided by meat which we should bear in mind when replacing meat in our diet include protein, iron and vitamin B12. The amino acid composition of proteins is an important consideration as well. The nutritional value of meat depends on the type of meat. The protein content of meat is around 25–31%, the fat content is 5–25%, the iron content is 1.3–3 mg per 100 g, the sodium content is 70–730[4] mg per 100 g and the amount of vitamin B12 is 0.3–2.1 µg per 100 g (RIVM, 2016). In general, meat contains no dietary fibre. The nutritional value of the most commonly consumed meat substitute products is shown in Table 3.

Table 3. The nutritional value of various meat substitute products (RIVM, 2016).

Nutrient	100 g meat substitute guideline	100 g egg	100 g meat substitute	100 g pulses	100 g nuts
Protein (g)	>12E%[5]	12.3	14.7	8	21.4
Fat (g)		8.8	8.2	0.9	55.3
Sodium (mg)		149	616	2	2
Vitamin B1 (mg)	>0.06	0.06	0.1	0.1	0.2
Vitamin B12 (µg)	0.24	1.54	0.24	0	0
Iron (mg)	>0.8	2.4	1.9	2	3.4
Fibre (g)		0	4	7.2	5.8

[4] The sodium content of processed meat products can be very high.
[5] E% stands for energy per cent. This means that according to the guideline >12% of the number of kilocalories in the meat substitute must be in the form of proteins.

Ideally, comparisons between meat and meat substitutes should take account of the nutritional value of the products. However, no system has yet been developed for comparing the nutritional contributions made by different foods. In this analysis comparisons are made at the product level based on the mass of each product.

In the results section (Chapter 4) we report both the kg CO_2 equivalent per kg of consumed product and the kg CO_2 equivalent per portion of meat or meat substitute in a recipe. The latter is used when determining the reduction in CO_2 emissions per recipe and the total impact of the campaign (see also Chapter 5).

2.3 System boundaries

The system boundaries define which phases of the life cycle are included in the analysis. Typical boundaries are cradle-to-gate, gate-to-gate and cradle-to-grave. A cradle-to-grave system boundary is used for comparing meat with meat substitutes. It brings all relevant supply chains for the production of meat and meat substitutes within the scope of the study. All processes that occur after 'the plate' are not taken into consideration, except for the treatment of food waste and product packaging waste. This is illustrated in the flow diagram in Figure 1. The colours of the arrows represent the following elements: **orange** – meat/meat substitute, including the supply chain of raw materials/ingredients; **green** – raw materials and emissions; **blue** – packaging in the production chain; **yellow** – energy carriers in the form of electricity, diesel and/or natural gas. Almost all processes need an energy input for processing, refrigeration, transport, cooking, etc.

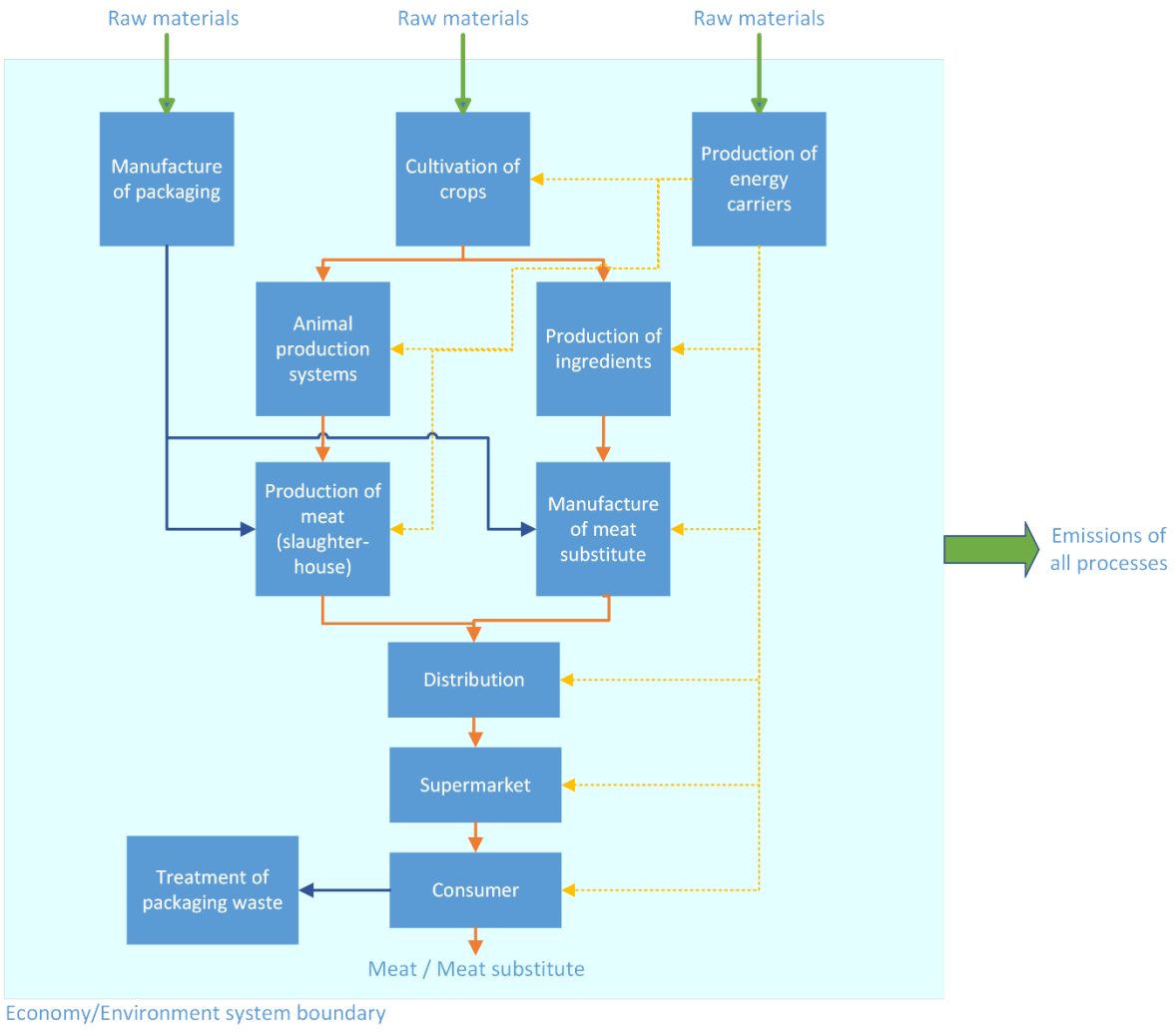

Figure 1 Diagram showing the system boundaries used in this analysis..

2.4 Comprehensiveness

In this study we aimed to make the most comprehensive analysis of the products as possible. An overview of what has and has not been included in each product phase in given Table 4.

Table 4. Overview of aspects included and excluded in each of the product phases.

Product phase	Included	Excluded
Cultivation of crops and production of animal products	- Use and production of nutrients - Use and production of fuels - Use and manufacture of plant protection products - Water for irrigation	- Capital goods (machines, buildings, etc.)
Manufacture of meat products/meat substitutes	- Ingredients (minimum 95%), including supply chain - Energy (electricity and/or gas), including supply chain - Packaging (cardboard, plastic, etc.) including supply chain	- Capital goods - Secondary and tertiary packaging
Distribution	- Transport to distribution - Refrigeration during distribution - Lighting during distribution - Losses in distribution (1%)	- Capital goods - Secondary and tertiary packaging
Supermarket	- Transport to supermarket - Refrigeration in supermarket - Lighting in supermarket - Heating in supermarket - Losses in retail	- Capital goods - Secondary and tertiary packaging
Consumer	- Refrigeration at consumer - Energy for cooking the product - Butter & oil for cooking the product - Mass losses during cooking of the product - Avoidable losses at consumer - Treatment of packaging waste	- Capital goods - Transport to consumer - Secondary and tertiary packaging

The ingredients for each product were identified at the supplier. Some background data on ingredients were missing, which can present a problem for meat substitutes in particular because these products consist of a range of different ingredients. However, meat and meat substitutes will consist of at least 90% of the ingredients (by mass).

2.5 Allocation of environmental impact

Allocation is about the division of environmental impact between products which a co-produced within a single process. An example is dairy production in which milk is produced and animals are slaughtered for meat (male calves and cows after their productive years). The environmental impact of dairy farming and all the previous phases in the life cycle have to be divided between these co-products. Other examples of co-production are the crushing of soybeans to produce oil and soybean meal, and the milling of maize and wheat to obtain flour and milling residues used in animal feed. In most cases we use the economic allocation method, in which the allocation key is calculated on the basis of the financial yields of the co-products. The only exception is dairy farming, for which the environmental impact is allocated on the basis of the energy the cow needs for the production of milk, the calf and meat (IDF, 2010).

2.6 Carbon footprint

Food production involves several environmental themes, such as CO_2 emissions, water use and land use. These environmental indicators can be determined by the LCA. For the 'Vegetarian Top Dishes Campaign 2019' campaign only the climate change impact was calculated. The climate is one of the big challenges of our time.

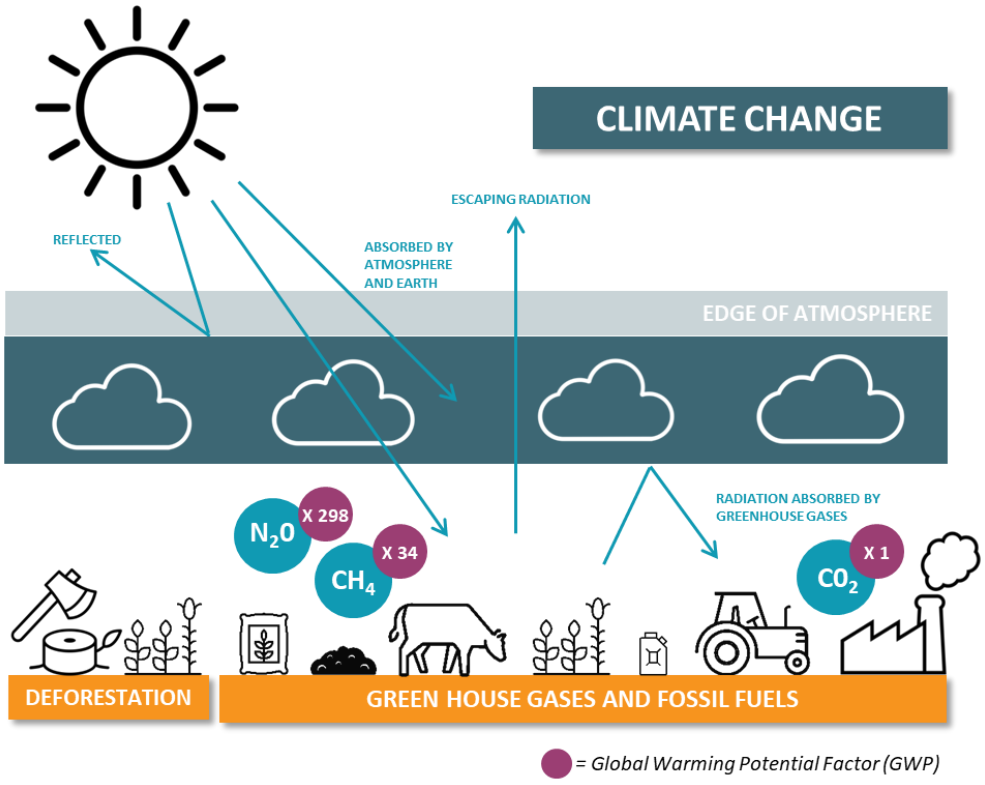

Figure 2 The processes contributing to climate change.

The increase in greenhouse gas concentrations in the atmosphere is gradually warming up the Earth, which has consequences for the quality of life. Climate change is caused by a combination of factors, such as biotic processes, plate tectonics and variations in solar radiation. Human activities, such as the combustion of fossil fuels, agriculture and deforestation, also have a significant influence on climate change. All these processes lead to higher concentrations of greenhouse gases in the atmosphere that cause climate change. Carbon dioxide (CO_2) is one of these greenhouse gases; other greenhouse gases that contribute to global warming include methane (CH_4) and nitrous oxide (N_2O). These other gases have also been included in the analysis and are expressed in equivalents with the same impact as that of CO_2 (see Figure 2). That is why the unit we use to measure the contribution made to climate change is kg CO_2 equivalents. One kilogram of nitrous oxide (N_2O) is equivalent in its effect to 298 kg of CO_2. We can also say that nitrous oxide has a global warming potential (GWP) of 298 kg CO_2 eq. Biogenic methane has a GWP of 34 kg CO_2 eq (IPCC, 2013).

3. Life cycle inventory

To calculate the environmental impact of agricultural products and foods you need a lot of data. Information is needed on things like yield per hectare, the use of fertilisers and diesel during cultivation, the composition of animal feed, feed conversion ratios and emissions during livestock production. Further along the life cycle, during the processing of agricultural produce into ingredients for example, much data is needed on energy use, food losses and mass concentration (water loss or addition during cooking).

For some products in the 'Vegetarian Top Dishes Campaign 2019' campaign, we used data from earlier studies by Blonk Consultants. For products for which no environmental data were available we made new analyses using data on ingredients, energy use and packaging materials obtained from the manufacturer. Table 5 lists all the products in the campaign and the sources of the environmental data used in the LCA (either from a previous study or from an analysis carried out for this project).

Table 5. Sources of data on the products in the 'Vegetarian Top Dishes Campaign 2019' campaign.

Product	Source of environmental information
Vegan Magic Mince (The Vegetarian Butcher)	Blonk analysis carried out for this project
Vegan Chicken Chunks (The Vegetarian Butcher)	(Broekema & van Paassen, 2017)
Vegetarian mc2 Burger (The Vegetarian Butcher)	Blonk analysis carried out for this project
Vegetarian mini meatballs (The Vegetarian Butcher)	Blonk analysis carried out for this project
Vegetarian sausage (*bratwurst*) (The Vegetartian Butcher)	Blonk analysis carried out for this project
Vegetarian smokey hotdog (The Vegetarian Butcher)	Blonk analysis carried out for this project
Vegetarian frankfurter (*knakworst*)	Blonk analysis carried out for this project
Vegetarian tomato soup	Blonk analysis carried out for this project
Vegetarian pâté	Blonk analysis carried out for this project
Vegetarian stew with lentils	Blonk analysis carried out for this project
Hellmans vegan mayonnaise	Blonk analysis carried out for this project
Chilli beans	Blonk analysis carried out for this project
Mushroom burger	Blonk analysis carried out for this project
Tomato soup	Blonk analysis carried out for this project
Chicken stew with lentils	Blonk analysis carried out for this project
Chicken ragout	Blonk analysis carried out for this project
Vegetarian ragout	Blonk analysis carried out for this project
Vegetable burger	(Broekema & Blonk, 2009)
Lentils	(van Paassen, Braconi, & Kuling, 2019)
Unsalted cashew nuts	(van Paassen et al., 2019)
Chestnut mushrooms	(van Paassen et al., 2019)
Chickpeas	(van Paassen et al., 2019)
Frankfurters (*knakworsten*)	(van Paassen et al., 2019)
Pâté	(van Paassen et al., 2019)
Mayonnaise	(van Paassen et al., 2019)

3.1 Life cycle phases

Primary and secondary data sources were used to model the different production systems. Primary data were obtained from the suppliers of the meat substitutes. Sources of secondary data were reports and other work previously carried out by Blonk Consultants for similar studies. All these data were brought together to determine the environmental impacts of the products. First we describe the primary and secondary data sources used for the following phases:

- manufacture of meat substitutes;
- distribution;
- supermarket;
- consumer.

Then we describe the various background processes used in the calculation of the environmental impacts.

3.1.1 Manufacture of meat and alternative products

The best sources of information on the manufacture of meat substitutes and the amounts of packaging materials are primary data obtained from the manufacturers. The manufacturers were asked to supply data on the composition of their products, the energy used in the processing of the products and the amount and type of packaging materials used, including the weights of the products. If one or more of the three components were missing, the relevant data were derived from other sources, on the condition that primary data were available at least on the product composition.

- Data on energy for manufacture were derived from a 'default' energy input. These default values were developed for the RIVM (National Institute for Public Health and the Environment) food database (van Paassen et al., 2019). For each type of process (extrusion, mixing, washing, etc.) a calculation was made based on previous studies by Blonk Consultants. The information on meat substitutes was based on processing by extrusion.
- Where no primary data were available on packaging materials, a default packaging was selected. These standard defaults for each type of packaging are based on previous studies by Blonk Consultants and were developed for the RIVM food database (van Paassen et al., 2019).

Table 6 shows the use of primary and default data for each of the products.

Table 6. Primary and default data on the manufacture of meat products and alternatives.

Product	Product composition	Energy use of manufacture	Packaging
Vegan Magic Mince (The Vegetarian Butcher)	Primary data	Default	Primary data
Vegetarian mc2 burger (The Vegetarian Butcher)	Primary data	Default	Primary data
Vegetarian mini meatballs (The Vegetarian Butcher)	Primary data	Default	Primary data
Vegetarian sausage (bratwurst) (The Vegetarian Butcher)	Primary data	Default	Primary data
Vegetarian smokey hotdog (The Vegetarian Butcher)	Primary data	Default	Default
Vegetarian frankfurter	Primary data	Default	Primary data
Vegetarian tomato soup	Primary data	Default	Primary data
Vegetarian pâté	Primary data	Default	Primary data
Vegetarian stew with lentils	Primary data	Default	Primary data
Hellmans vegan mayonnaise	Primary data	Default	Primary data
Chilli beans	Primary data	Default	Primary data
Mushroom burger	Primary data	Default	Primary data
Tomato soup	Primary data	Default	Primary data
Chicken stew with lentils	Primary data	Default	Primary data
Chicken ragout	Primary data	Default	Primary data
Vegetarian ragout	Primary data	Default	Primary data

3.1.2 Distribution and retail

Transport distances and energy use during distribution and retail were derived from the food database developed for RIVM (van Paassen et al., 2019) (see Table 7). It was assumed that meat and meat substitutes sold in the refrigerated section of the supermarket are refrigerated during transport.

Table 7. Assumed transport distances and energy use during the transport and retail phases (van Paassen et al., 2019).

Item	Default Distribution	Default Retail
Transport distance	20 km	50 km
Food losses	1%	Per product category (PEFCR[6])
Refrigeration	50 kWh/tonne	30 kWh/tonne
Lighting	40 kWh/tonne	36 kWh/tonne
Heating	Not relevant	284.4 kWh/tonne

3.1.3 Consumer

The consumer phase consists of various components.

- Storage of the product by the consumer: electricity use for refrigeration was determined using a model developed by Blonk Consultants for Milieu Centraal (van Zeist, Kuling & Scholten, 2015) and amounted to 27 kWh per tonne of product.
- Cooking the product: cooking of products requires energy in the form of gas and electricity. For the cooking of food it is assumed from information in the Energy Transition Model that 40% of cookers are electric and 60% are gas. The cooking model is based on a previous project carried out by Blonk Consultants for RIVM (Broekema, Kuling & Scholten, 2015).
- Mass loss from the product during cooking was based on a previous project carried out by Blonk Consultants for RIVM (van Paassen et al., 2019) and is the 'raw-to-cooked' ratio. Examples are beef mince, which loses 15% of its weight during cooking, and mushrooms, which lose around 30% of their raw weight.
- Butter and oil for cooking the product: it was assumed that 40 g of sunflower oil or 40 g of butter are used per kg of cooked product. This assumption was made for all products included in this study that are fried. For other cooking methods, such as boiling (soup), microwave (smoked sausage) or no cooking (pâté), it was assumed that no oil or butter is used.
- Treatment of packaging waste: the amounts of plastic, cardboard and tinplate (cans) that have to be treated are the same as the amounts used in the product packaging. The waste treatment and recycling routes were determined according to the Circular Footprint Formula (CFF) described in the PEFCR (European Commission, 2018).

3.1.4 Losses in the food chain

Losses during the whole life cycle of meat and meat substitutes are assumed to be the following:

- 1% loss during distribution (van Paassen et al., 2019);
- loss at the supermarket as prescribed in the PEFCR (European Commission, 2018);
- losses after cooking based on losses of meat and vegetables (Van Westerhoven & Steenhuizen, 2010).

3.2 Agri-footprint

For much of the background data, such as the environmental information on cultivation and the processing of ingredients, use was made of Agri-footprint®, the world's leading life cycle inventory database of agricultural products and foods. This database contains data on more than 5,000 agricultural products and processes and is

[6] Product Environmental Footprint guidelines developed by the European Commission (European Commission, 2018)

regularly updated. Agri-footprint® data were also used for electricity production, transport and the manufacture of packaging. Where Agri-footprint did not contain information on specific packaging materials, use was made of EcoInvent.

4. Results: Carbon footprint

The diagram below shows the reported results for CO_2 emissions in kg CO_2 eq / kg product for the meat benchmark products, the meat substitutes and the alternative vegetarian options used in the ten recipes (see Figure 3).

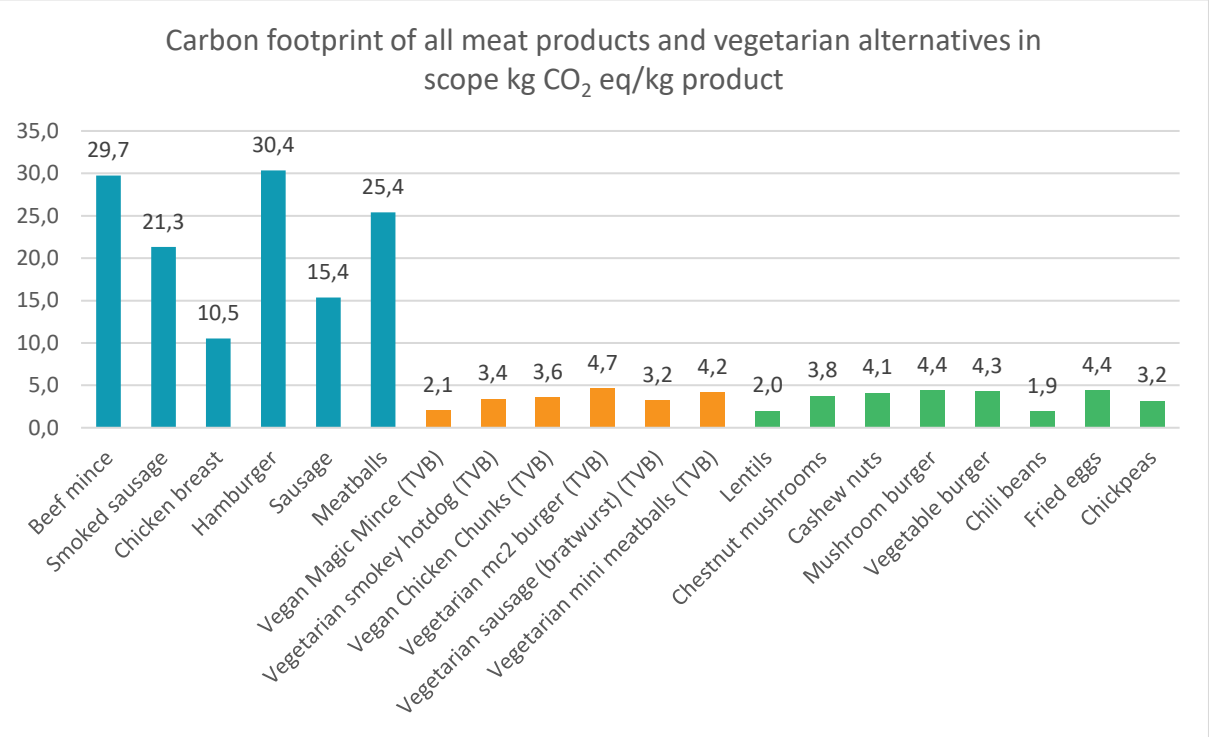

Figure 3 CO_2 emissions per kilogram of the products in scope: meat benchmark products (blue), meat substitutes (orange), alternative vegetarian options (green).

In the next sections we briefly describe the environmental impacts of each recipe and the differences between them, picking out the relevant phases in the life cycle in a hotspot analysis. Bear in mind that the amounts of product in the meat and meat substitute recipes differ from those used in the alternative vegetarian options. All these amounts are based on the recipes used in the campaign, which were compiled to be nutritionally consistent with Netherlands Nutrition Centre guidelines.

The following phases in the life cycle were considered in the assessment:

Ingredients

This phase includes the production of the ingredients used to make the product, such as the cultivation of crops and production in animal husbandry systems, as well as the processing of animal products and agricultural crops. An example is the cultivation of soybeans and the manufacture of soy protein, a much used ingredient in meat substitutes.

Land use change

Land use change is also included in the ingredients group, but is always indicated separately because the modelling contains uncertainties and depends heavily on assumptions. Some agricultural production systems are expanding at the cost of natural ecosystems, usually accompanied by climate change impacts. One of the most problematic examples is the conversion of forest in Brazil and Indonesia for the production of soy and palm oil. The greenhouse gases released are converted to CO_2 equivalents.

Energy (for manufacture)

This phase contains the energy used in the manufacture of the product for processes such as heating, mixing and extrusion of ingredients. For meat products this includes energy used in the slaughterhouse and for meat processing.

Packaging

Packaging includes the manufacture of packaging materials and the processes involved in packaging the product itself, such as the manufacture of PET from oil and the moulding of PET containers from PET granules.

Distribution & retail

This phase includes energy use during distribution and retail, such as electricity for refrigeration, logistics and fuel used for transport to distribution centres and retailers (see also section 3.1.2).

Consumer

The consumer phase consists of the storage and cooking of the food. The treatment of waste packaging and food waste is also included in this phase (see also section 3.1.3).

4.1 Spaghetti Bolognese with vegetarian mince

Choosing spaghetti Bolognese with vegetarian mince instead of beef mince reduces the carbon footprint impact of a meal for four by 4.4 kg CO_2, a 92% decrease from the same meal with beef mince. Replacing beef mince with lentils reduces CO_2 emissions by 4.1 kg.

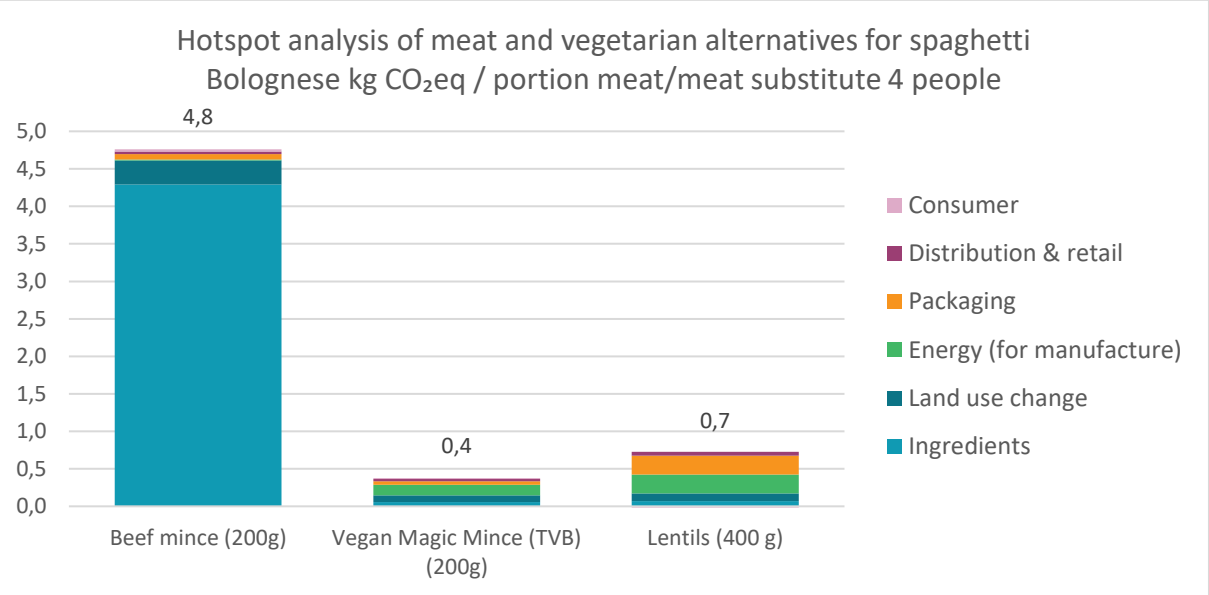

Figure 4 Hotspot analyses of the CO_2 emission of beef mince (meat benchmark), Vegan Magic Mince (TVB) (meat substitute) and lentils (alternative vegetarian option). The amounts given are for the recipe for spaghetti Bolognese for four people.

The climate change impact of beef is about 30 kg CO_2 eq / kg (see Figure 3). Figure 4 shows that the high CO_2 emissions of beef mince are caused mainly by the ingredients (± 96%, incl. land use change), in this case the production of meat on the farm. The production of animal feed, the management of manure (storage and application) and methane emissions from rumen fermentation are major sources of these emissions. Packaging accounts of 1.6% and distribution and retail just 0.7%.

Beef can be produced in different systems. It can be produced from beef cattle, but also in co-production with milk in dairy farm systems. In general, beef from dairy farming has a lower carbon footprint per kg because part of the CO_2 emissions is allocated to the produced milk (see also section 2.5). Of the beef produced in the

Netherlands, 65% is from dairy cattle and 35% is from beef cattle. This division is used in the analysis for this study.

A pack of vegetarian mince (200 g) has an emission of 0.4 kg CO_2 eq. Figure 4 shows that the CO_2 emissions of the ingredients and land use change phases are considerably lower than for beef mince. As no animal system is involved, there is no production of animal feed and no emissions form manure or rumen fermentation.

The energy used in the manufacture of the vegetarian mince, however, has a higher CO_2 emission than the processing of beef mince. It makes up 37% of the total and consists of electricity and heat for extrusion. The packaging consists of a plastic tray and a cardboard sleeve and contributes 12% of total emissions. The distribution & retail and consumer phases make up 8% and 3% of the total.

The lentils option has a slightly higher CO_2 emission than vegetarian mince. This is mainly due to the difference in energy use for the production and packaging of a can of lentils (36%), which is used mainly in the processes involved in canning the lentils, such as heating, washing and centrifuging. The packaging (35%) consists of a can with a paper sleeve, with the can making the biggest contribution.

4.2 Endive mashed potato with vegetarian smoked sausage

Choosing endive mashed potato (*andijviestampot*) with vegetarian smoked sausage instead of the regular (meat-based) smoked sausage (*rookworst*) reduces the carbon footprint impact of a meal for four by 4.2 kg CO_2, an 84% decrease from the same meal with regular smoked sausage. Replacing beef mince with chestnut mushrooms reduces the CO_2 emissions by 4.5 kg.

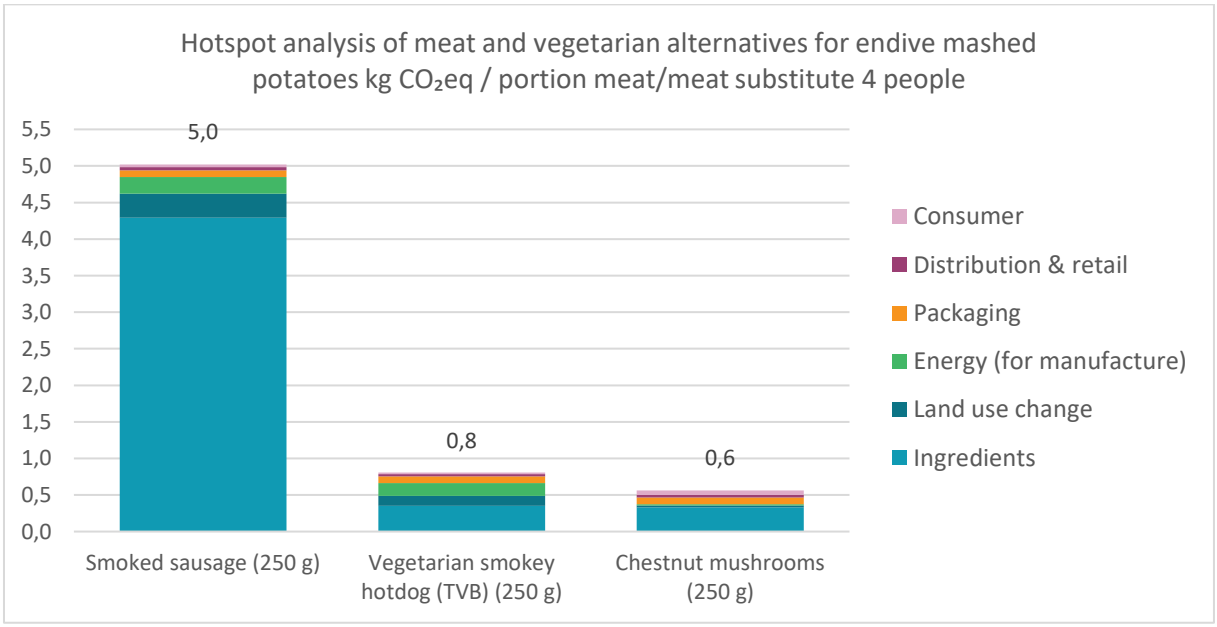

Figure 5 Hotspot analyses of the CO_2 emission of smoked sausage (meat benchmark), vegetarian smokey hotdog (TVB) (meat substitute) and chestnut mushrooms (alternative vegetarian option). The amounts given are for the recipe for endive mashed potato for four people.

Figure 5 shows that the high CO_2 emissions of smoked sausage are mainly due to the ingredients (± 85%). It is assumed that the smoked sausage is made from beef and has the same source composition as beef mince (65% from dairy cattle and 35% from beef cattle). See section 4.1 for a description of the CO_2 emissions of beef production. The energy used for manufacture contributes 5% to the total carbon emissions and consists of electricity and heat for intensive meat processing techniques.

The carbon emission of vegetarian smoked sausage (250 g) is 0.8 kg CO_2 eq, which is considerably lower than for beef smoked sausage. The production of ingredients including land use change accounts for 61% of total carbon emissions, with the biggest contribution coming from the manufacture of sunflower oil and chicken egg protein

(ingredients of the vegetarian smoked sausage). The energy used in the manufacture of the smoked sausage contributes 22% of the emissions and consists of electricity and heat for the processing of ingredients to make vegetarian smoked sausage. Packaging accounts for 12%, the distribution and retail phase contributes 4% and the consumer phase 2%.

A 250 g tray of chestnut mushrooms has a total carbon emission of 0.6 kg CO_2 eq. The largest share of this, 63% (incl. land use change), is from the cultivation of the chestnut mushrooms. The other phases contribute 37%, of which 16% is from the plastic tray and 11% from the consumer phase (cooking the chestnut mushrooms and treatment of the waste packaging).

4.3 Indonesian stir fried rice with vegetarian chicken pieces and peanut sauce

Choosing Indonesian stir fried rice (*nasi goreng*) with vegetarian chicken pieces instead of chicken breast reduces the carbon footprint impact of a meal for four by 0.6 kg CO_2, a 55% decrease from the same meal with chicken breast. Replacing chicken breast with cashew nuts reduces CO_2 emissions by 0.4 kg.

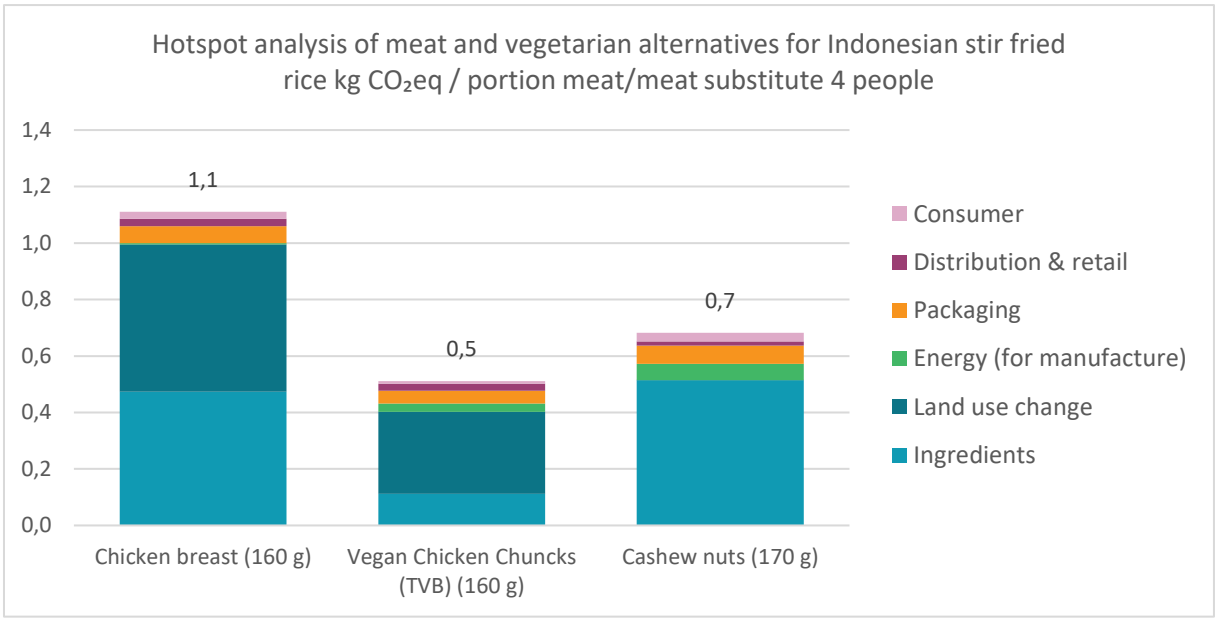

Figure 6 Hotspot analyses of the CO_2 emission of chicken breast (meat benchmark), Vegan Chicken Chunks (TVB) (meat substitute) and cashew nuts (alternative vegetarian option). The amounts given are for the recipe for Indonesian stir fried rice for four people

Chicken has a much lower carbon footprint impact than beef products. Emissions of CO_2 per kilogram of chicken are around 10 kg CO_2 eq, compared with about 30 kg CO_2 eq / kg for beef. This is why the differences between the meat version and the vegetarian options for this recipe are smaller than for the spaghetti Bolognese and endive mashed potato recipes.

The 1.1 kg CO_2 eq for 160 g of chicken breast come mainly from the ingredients plus land use change (90%, see Figure 6). In this case, these emissions are from the production of broilers and the feed. The land use change component, at 47%, concerns the production of soybeans in South America. The beans are turned into soy meal, which is one of the main ingredients of chicken feed. Packaging accounts for 5%, the distribution and retail phase contributes 2% and the consumer phase 2%.

The 0.5% kg CO_2 eq for a pack of vegetarian chicken pieces (160 g) is much lower than for the chicken breast, mainly because of the reduction in emissions of the ingredients and land use changes phases. The CO_2 emissions of the ingredients are mainly from the production of soy protein concentrate, one of the main ingredients of the vegetarian chicken pieces. The energy used in the processing of the ingredients into vegetarian chicken pieces contributes 6% of total carbon emissions, the packaging 9% and the distribution and retail phase 5%.

The 0.7 kg CO_2 eq for 170 g of cashew nuts is mainly from the production of the cashew nuts on cashew plantations (75%). The main factor in the size of these emissions is the relatively low yields per hectare of cashew nuts. The shelling and processing of the cashew nuts (energy for manufacture) contributes 9% of the total.

4.4 Vegetable burger and chips

Choosing chips and a Mc2 burger instead of a hamburger reduces the carbon footprint impact of a meal for four by 5.6 kg CO_2, an 82% decrease from the same meal with a regular hamburger. Replacing a hamburger with a mushroom burger reduces CO_2 emissions by 5.7 kg.

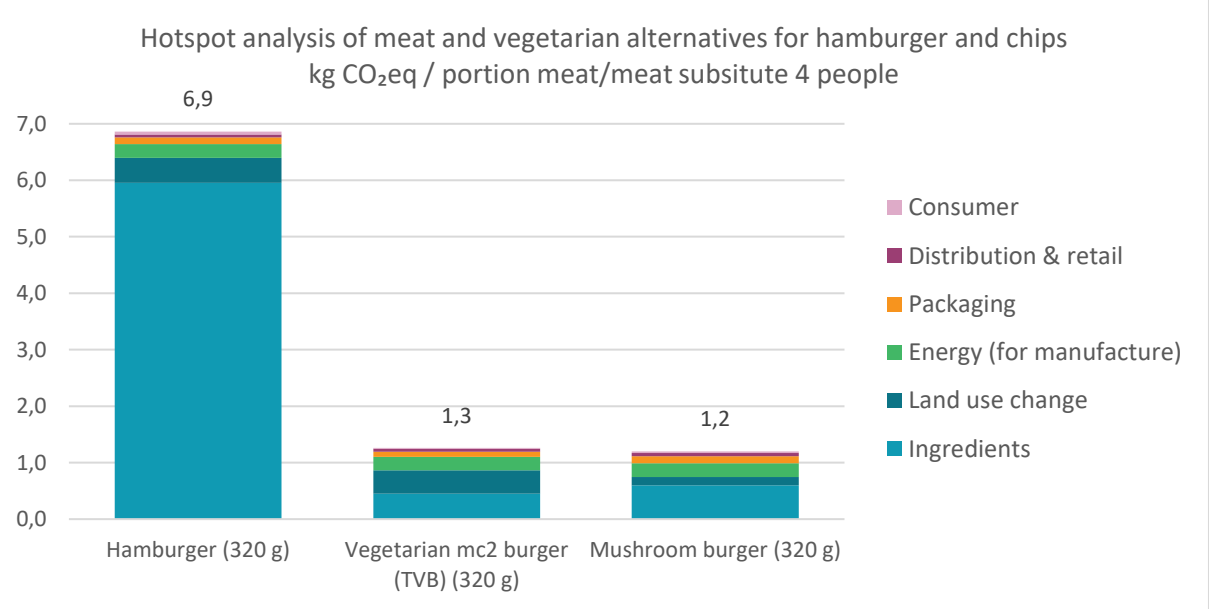

Figure 7 Hotspot analyses of the CO_2 emission of hamburgers (meat benchmark), Vegetarian mc2 burger (TVB) (meat substitute) and mushroom burgers (alternative vegetarian option). The amounts given are for the recipe for hamburger and chips for four people.

Figure 7 shows that the high CO_2 emissions of hamburgers are mainly due to the ingredients (87%). It is assumed that the hamburger is made from beef mince consisting of 65% beef from dairy cattle and 35% from beef cattle. See section 4.1 for a description of the CO_2 emissions of beef production. The energy used in manufacture contributes 4% to total carbon emissions and consists of electricity and heat for intensive meat processing techniques.

The Vegetarian mc2 burgers (320 g) have a carbon emission of 1.3 kg CO_2 eq. The emissions reduction compared with the hamburger is due mainly to lower emissions during the ingredients phase. The biggest contributor to this phase is the production of chicken egg protein and sunflower oil (ingredients of the Vegetarian mc2 burger). Energy used for manufacture makes up 19% of total emissions. The plastic packaging accounts for 7%, the distribution and retail phase contributes 4% and the consumer phase 2%.

The mushroom burgers (320 g) have a total carbon emission of 1.2 kg CO_2 eq. The largest share, 62%, is from the ingredients and land use change phase. Energy used in the manufacture of the mushroom burger contributes 20%, the plastic tray contributes 11% and the distribution and retail phase 4%.

4.5 Vegetarian sausage with baby potatoes and cauliflower

Choosing a vegetarian sausage instead of a pork sausage (*bratwurst*) reduces the carbon footprint impact of a meal for four by 2.5 kg CO_2, a 72% decrease from the same meal with a pork sausage. Replacing a sausage with a vegetable burger reduces CO_2 emissions by 2.0 kg.

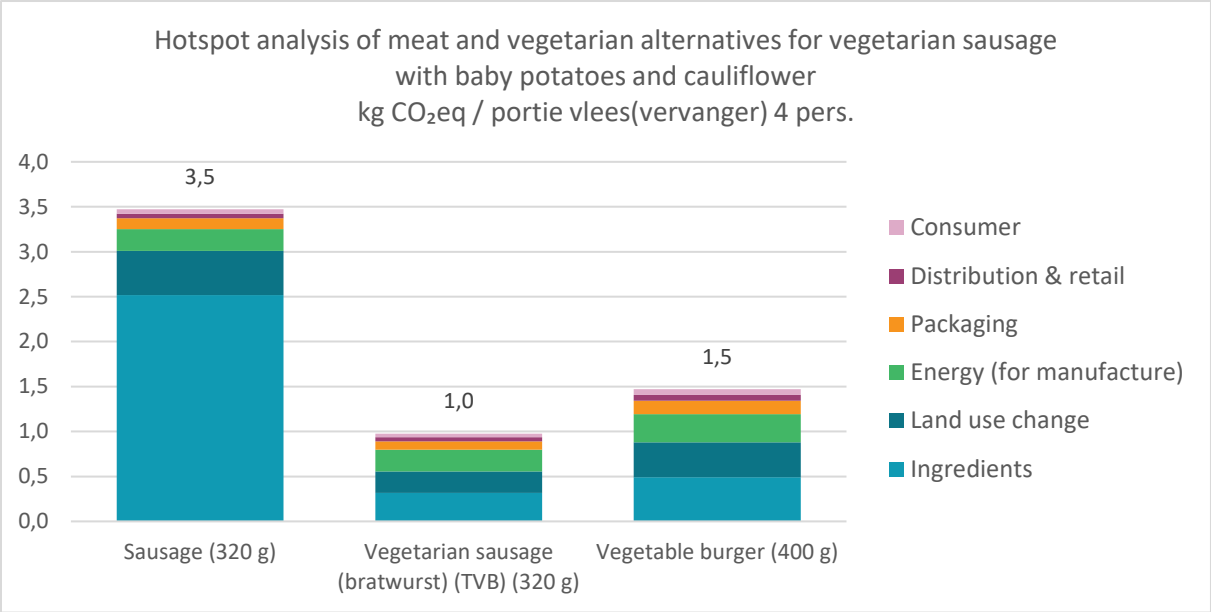

Figure 8 Hotspot analyses of the CO_2 emission of sausage (meat benchmark), vegetarian sausage (bratwurst (TVB) (meat substitute) and vegetable burger (alternative vegetarian option). The amounts given are for the recipe for sausage, baby potatoes and cauliflower for four people.

Figure 8 shows that the high CO_2 emissions of pork sausage are due mainly to the ingredients (73%) and land use change (14%). The production of animal feed and manure management are major sources of these emissions. Methane emissions from fermentation are less significant for pigs than for ruminants such as cows. For this reason, and because pigs have a more favourable feed conversion ratio[7] than cows, CO_2 emissions per kg of pork are lower than those of beef (see also Figure 3). Meat processing contributes 7% of the CO_2 emissions and packaging just 3%.

The 2.5 kg CO_2 eq lower emissions of 320 g vegetarian sausage compared with the meat sausage can be attributed to lower emissions in the ingredients and land use change phase. Two important ingredients that contribute to the CO_2 emissions are chicken egg protein and rape seed oil. Energy used in the manufacturing process makes up 25% of the total and is used for the processing of ingredients to make the vegetarian sausage. The plastic tray accounts for 9%, the distribution and retail phase contributes 5% and the consumer phase 4%.

The vegetable burgers (400 g) have a total carbon emission of 1.5 kg CO_2 eq. The ingredients, including land use change, contribute 60% of the CO_2 emissions. The energy used in manufacture contributes 21% and the plastic tray 10%.

[7] The feed conversion ratio is a measure of the efficiency with which an animal converts feed into animal products (e.g. meat, milk or eggs).

4.6 Burritos with vegetarian chicken pieces

Choosing burritos with vegetarian chicken pieces instead of chicken breast reduces the carbon footprint impact of a meal for four by 0.6 kg CO_2, a 54% decrease from the same meal with chicken breast. Replacing chicken breast with chilli beans reduces CO_2 emissions by 0.4 kg.

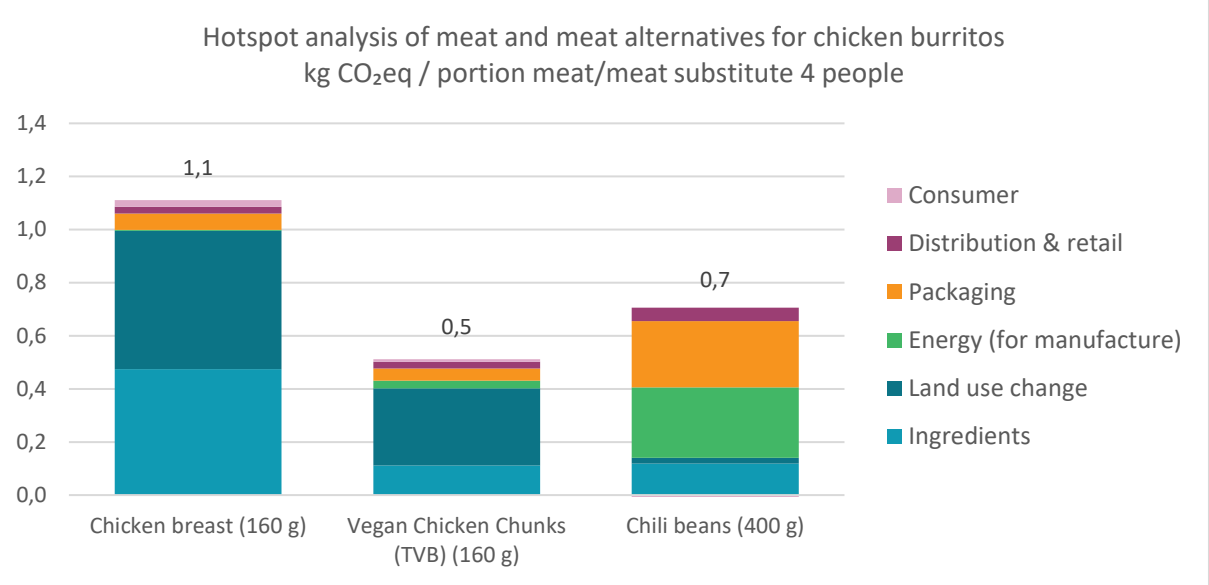

Figure 9 Hotspot analyses of the CO_2 emission of chicken breast (meat benchmark), Vegan Chicken Chunks (TVB) (meat substitute) and chilli beans (alternative vegetarian option). The amounts given are for the recipe for chicken burritos for four people.

Chicken has a much lower carbon footprint impact than beef or pork products. Emissions of CO_2 per kilogram of chicken are around 10 kg CO_2 eq, compared with ± 15 kg CO_2 eq / kg for pork and ± 30 kg CO_2 / kg for beef (see Figure 3). This is why the differences between the meat version and vegetarian options for this recipe are larger than for the recipes with pork or beef. See section 4.3 for a description of the CO_2 emissions of the production of chicken meat and vegetarian chicken pieces.

The 400 g chilli beans have a carbon emission of 0.7 kg CO_2 eq. The contribution made by the ingredients and land use change is relatively small at 20%. In contrast, the energy used for processing and packaging contribute 39% and 36% of the CO_2 emissions. Energy use consists mainly of the steps required to can the beans, including heating, washing and centrifuging. The packaging consists of a can with a paper sleeve, with the can making the biggest contribution.

4.7 Vegetable lasagne with vegetarian mince

Choosing vegetable lasagne with vegetarian mince instead of beef mince reduces the carbon footprint impact of a meal for four by 4.4 kg CO_2, a 92% decrease from the same meal with beef mince. Replacing beef mince with lentils reduces CO_2 emissions by 4.1 kg.

This recipe uses the same products and amounts of meat and vegetarian options as the recipe for spaghetti Bolognese. The description of the hotspots analysis of beef mince, vegetarian mince and lentils can be found in section 4.1.

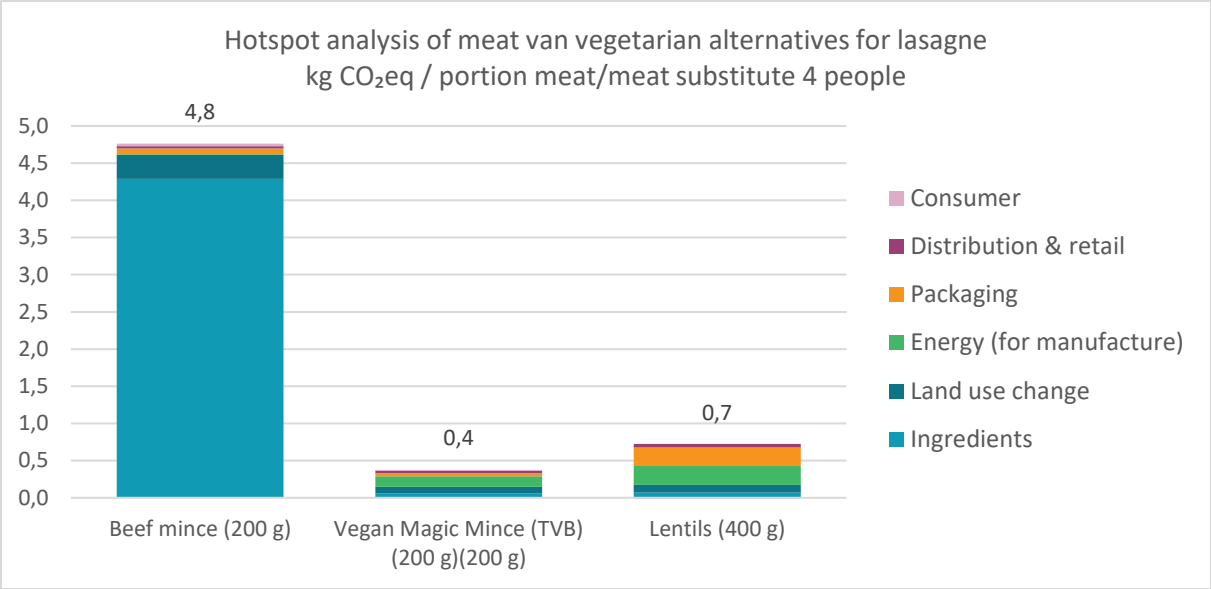

Figure 10 Hotspot analyses of the CO_2 emission of beef mince (meat benchmark), Vegan Magic Mince (TVB) (meat substitute) and lentils (alternative vegetarian option). The amounts given are for the recipe for lasagne for four people.

4.8 Indonesian stir fried noodles with vegetarian chicken pieces

Choosing Indonesian stir fried noodles (*bami goreng*) with vegetarian chicken pieces instead of chicken breast pieces reduces the carbon footprint impact of a meal for four by 0.6 kg CO_2, a 54% decrease from the same meal with chicken breast. Replacing chicken breast with fried eggs reduces the CO_2 emissions by 0.2 kg.

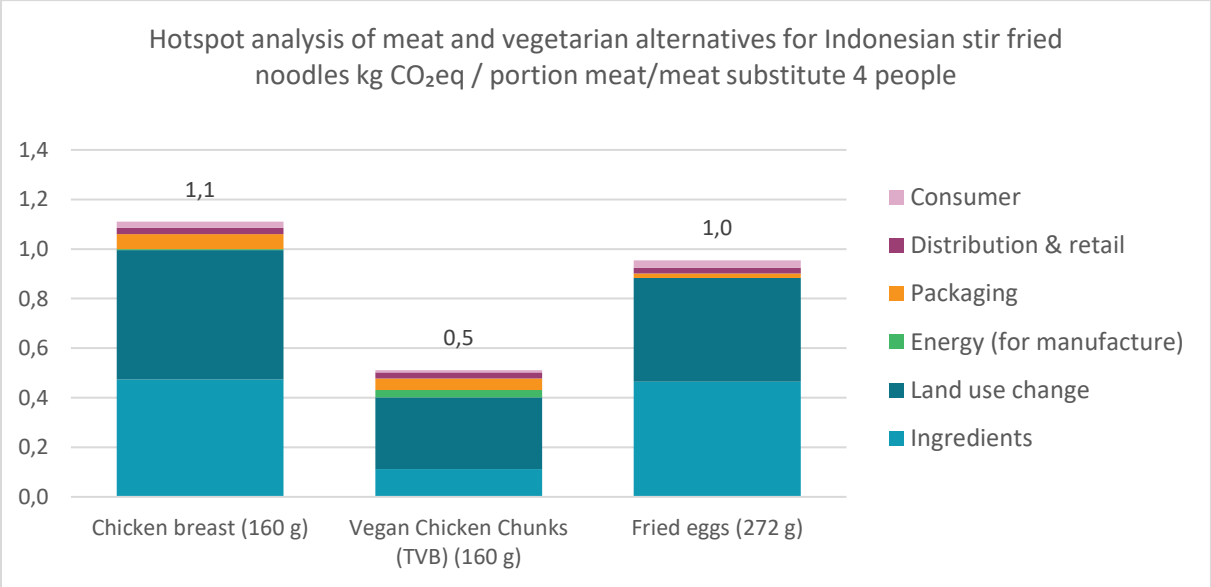

Figure 11 Hotspot analyses of the CO_2 emission of chicken breast (meat benchmark), Vegan Chicken Chunks (TVB) (meat substitute) and fried eggs (alternative vegetarian option). The amounts given are for the recipe for Indonesian stir fried noodles for four people.

A description of the hotspot analysis of chicken breast and vegetarian chicken pieces can be found in section 4.3.

Fried eggs (4 x 68 g) have a CO_2 emission of 1.0 kg CO_2 eq, which is almost the same as the emissions of 160 g of chicken breast. The production of the ingredients accounts for 49% of the emissions, which are mainly from laying hen farming and the chicken feed. The land use change component, at 44%, is from the production of soybeans in South America. These are turned into soy meal, which is one of the main ingredients of chicken feed. The packaging, distribution and retail, and consumer phases account for just 2%, 2% and 3% of the total.

4.9 Pumpkin soup with vegetarian meatballs

Choosing pumpkin soup with vegetarian mince instead of beef meatballs reduces the carbon footprint impact of a meal for four by 3.0 kg CO_2, an 83% decrease from the same meal with beef meatballs. Replacing beef meatballs with lentils reduces CO_2 emissions by 2.5 kg.

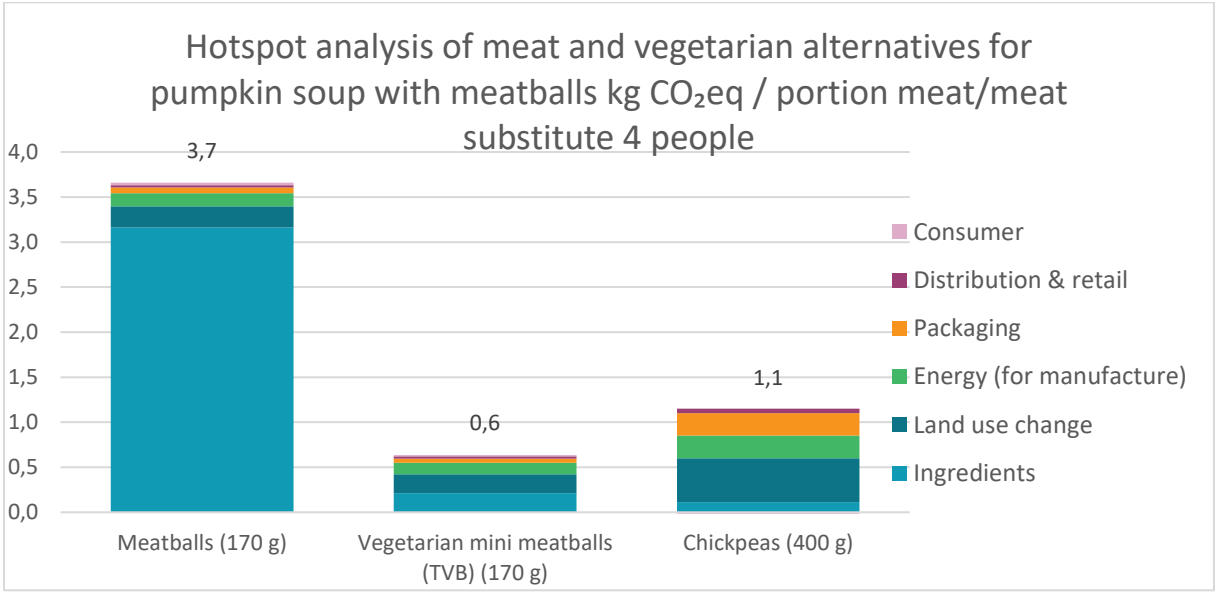

Figure 12 Hotspot analyses of the CO_2 emission of beef meatballs (meat benchmark), Vegetarian mini meatballs (TVB) (meat substitute) and chickpeas (alternative vegetarian option). The amounts given are for the recipe for pumpkin soup with meatballs for four people.

Figure 12 shows that the high CO_2 emissions of meatballs are mainly from the ingredients phase (± 93%, including land use change). It is assumed that the meatballs are made from beef consisting of 65% beef from dairy cattle and 35% from beef cattle. See section 4.1 for a description of the CO_2 emissions of beef production. The energy used for manufacture contributes 4% to the total carbon emissions and consists of electricity and heat for intensive meat processing techniques.

The 170 g vegetarian meatballs have a considerably lower impact of 0.6 kg CO_2 eq, mainly because of the lower CO_2 emissions of the ingredients compared with beef meatballs. One third of the emissions of vegetarian meatballs are from the ingredients, including chicken egg protein, soy protein and rape seed oil. Chicken egg protein and soy protein are the biggest contributors to the land use change emissions (33%).

The emission of the 400 g of chickpeas is 1.1 kg CO_2 eq and, like the vegetarian meatballs, is due to a considerably lower emission of the ingredients phase. However, the emissions of land use change, energy for manufacture and packaging phases are larger. The chickpeas are grown mostly in Argentina, which accounts for the relatively high level of land use change emissions (43%), which are caused by deforestation. Energy use (22%) is mainly for the processes involved in canning the lentils, including heating, washing and centrifuging. The packaging (22%) consists of a can with a paper sleeve, with the can making the biggest contribution.

4.10 Macaroni with vegetarian meatballs

Choosing macaroni with vegetarian meatballs instead of beef meatballs reduces the carbon footprint impact of a meal for four by 3.0 kg CO_2, an 83% decrease from the same meal with beef meatballs. Replacing beef meatballs with chestnut mushrooms reduces the CO_2 emissions by 3.1 kg.

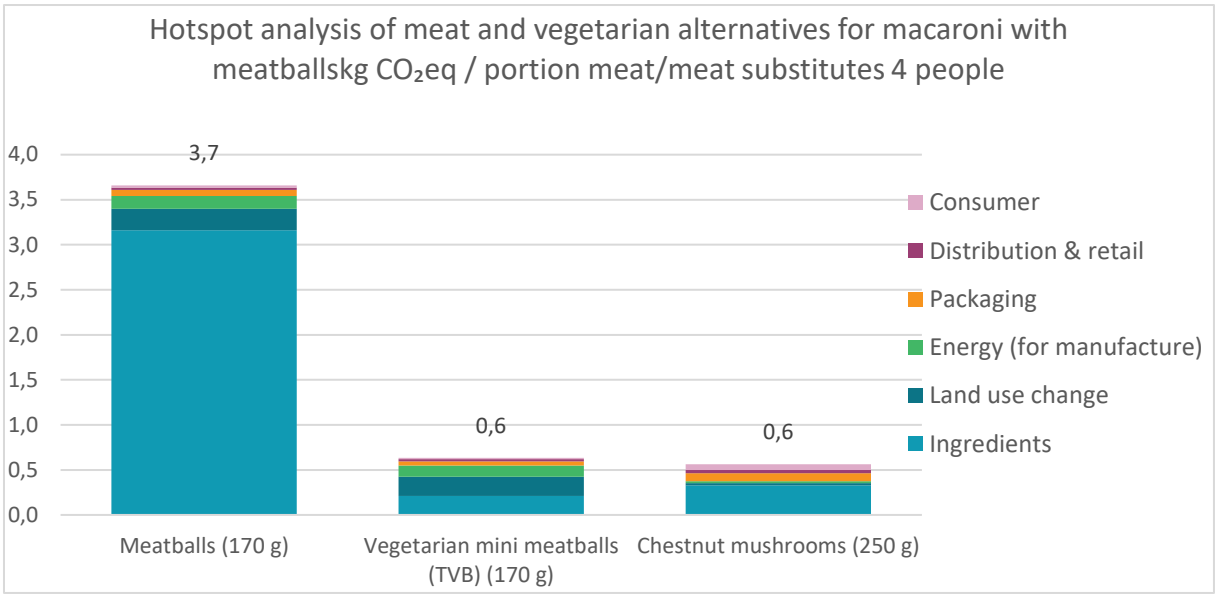

Figure 13 Hotspot analyses of the CO_2 emission of meatballs (meat benchmark), Vegetarian mini meatballs (TVB) (meat substitute) and chestnut mushrooms (alternative vegetarian option). The amounts given are for the recipe for macaroni with meatballs for four people.

This recipe uses the same products and amounts of meat and meat substitute as the recipe for pumpkin soup with meatballs. The description of the hotspots analysis of beef meatballs and vegetarian meatballs can be found in section 4.9.

The 250 g of chestnut mushrooms have a total CO_2 emission comparable with the 170 g of vegetarian meatballs (see Figure 13). However, the emissions are distributed differently across the various phases in the life cycle. The largest share, 63% (incl. land use change), is from the cultivation of the chestnut mushrooms. The other phases contribute 37%, of which 16% is from the plastic tray and 11% from the consumer phase.

4.11 Box of products

Instead of choosing one of the recipes, the National Postcode Lottery participants could exchange their voucher for a box of six vegetarian products. In the results we compare the products with their corresponding 'regular' products with animal ingredients.

The results for the box of vegetarian products show a 41% reduction in CO_2 emissions. The vegetarian products in the box have a combined carbon emission of 7.2 kg CO_2 eq, compared with 12.7 kg CO_2 eq for the box of regular products. Each individual vegetarian product was found to have a lower carbon footprint impact than its regular version (see Figure 14). The biggest reduction is made by the vegetarian frankfurter (68%). The calculation for regular frankfurters was based on an average composition of 50% pork and 50% beef. The reduction is expected to be somewhat less compared with a frankfurter made of 100% pork and a bit higher compared with a frankfurter made of 100% beef.

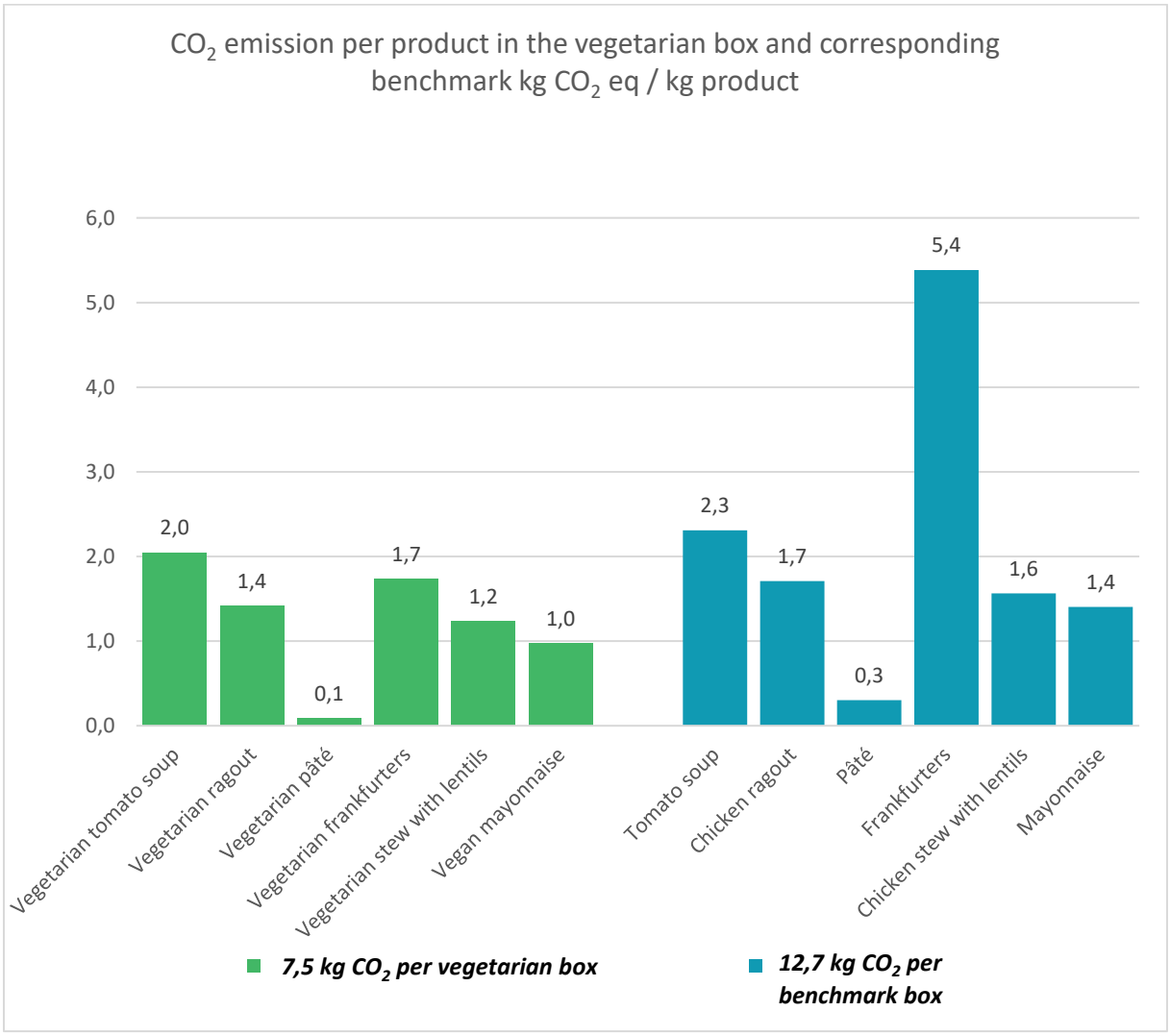

Figure 14 The CO_2 emissions of the box of vegetarian products and their corresponding benchmark products.

5. Total reductions

To calculate the total carbon emissions reduction achieved by the 'Vegetarian Top Dishes Campaign 2019' campaign we examined the additional sales of vegetarian products[8] during the campaign (Monday 28 October to Sunday 17 November 2019) compared with the benchmark sales. The benchmarks were the average sales volumes over the period from week 1 to week 42 in 2019. For seasonal products such as smoked sausage we took the average sales volume in the winter months in 2019 (weeks 1 to 10). Sales volumes in the campaign weeks were not included in the calculations of the average sales volumes.

5.1 Assumptions

It is assumed that the additional sales of meat substitutes and alternative vegetarian options in the ten recipes led to a decline in the same amount of meat products (in the equivalent recipe). See also Table 1 in the Introduction.

It is assumed that the additional sales of the six vegetarian products in the box led to a corresponding decline in the sales of regular products with animal ingredients. See also Table 2 in the Introduction.

In reality, a number of the people who used the voucher were probably already vegetarians and would have bought a meat substitute in any case (at an Albert Heijn or other supermarket). However, this effect is likely to be minimal as the number of vegetarians in the Netherlands is still relatively small (4.4% according to the latest national food consumption survey by RIVM in 2016).

5.2 Total impact

During any three week period outside the campaign the average sales of the vegetarian products in scope are 799,986 units. During the three weeks of the campaign sales of these products were 2,010,276 units, 43% of which were bought using the National Postcode Lottery voucher and 57% without the voucher (see Figure 15).

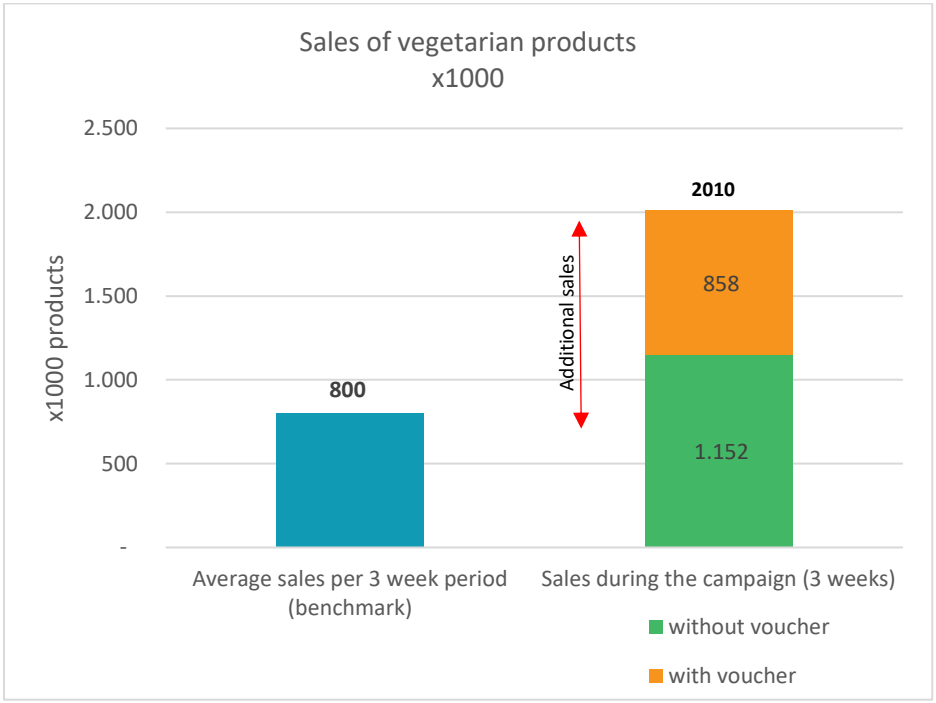

Figure 15 Sales of the vegetarian products in scope during a three week period.

[8] Vegetarian products includes all meat substitute and alternative vegetarian options in the ten vegetarian recipes plus the vegetarian products in the box.

The additional sales of vegetarian products during the campaign period amounted to 1,210,290 units. Of these, 71% were bought with the gift voucher and 29% without the voucher.

The total carbon emissions reduction achieved by the 'Vegetarian Top Dishes Campaign 2019' campaign was

2,752 tonnes CO_2 eq

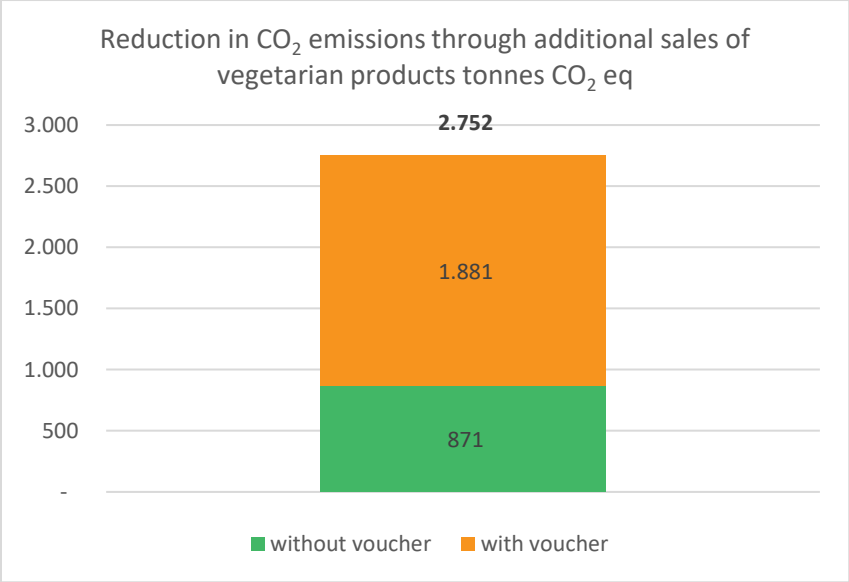

Figure 16 Total CO_2 reduction achieved through the additional sales of vegetarian products in scope, assuming that these products replaced the meat-based benchmark products.

This reduction is equivalent to the CO_2 emissions of:

- 15.7 million car kilometres, or
- 3,177 flights from Amsterdam to New York.

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Blonk Consultants
Gravin Beatrixstraat 34
2805 PJ Gouda

(+31) 0182 579970
www.blonkconsultants.nl
info@blonkconsultants.nl

blonk consultants