



INSTITUTET FÖR LIVSMEDEL OCH BIOTEKNIK

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# Environmental Life Cycle Assessment (LCA) of ready meals

**LCA of two meals; pork and chicken  
&  
Screening assessments of six ready meals**

*Johanna Berlin*

*Veronica Sund*



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**Double Fresh**  
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## **Double Fresh**

Towards a new generation of healthier and tastier ready-to-eat meals  
with fresh ingredients

### **D7.8 Scientific publication on environmental impact of the new RTE meal concepts in comparison to the existing offerings.**

Organisation name of lead contractor for this deliverable: **SIK** –the Swedish Institute  
for Food and Biotechnology AB

## **Project Information**

### **Project start**

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### **Project group**

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### **Project group**

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### **Keywords**

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## Abstract

The wastage of food along the food chain is a large negative environmental contributor in a system perspective. For vegetables the wastage can be as high as 45% at the UK households (Ventour, 2008). The wastage of ready meals is also high; in the Netherlands the wastage at the retailer can be as high as 20% depending on the dish. Due to that all foods and ingredients that ends up as wastage has been produced, the environmental burden already occurred has been made for nothing.

The aim of these environmental assessments was to quantify the environmental improvement potential possible by decreasing the wastage of ready meals at the retailers from 20% to 5%. Two in depth LCA assessments were fulfilled and six screening assessments. For the in depth assessment one ready-to-eat meal were chosen; Hunter's meal which consisted of pork, mashed potatoes mushroom sauce and carrots. The Hunter's meal was produced in Finland. A ready-to-eat meal just needs heating before consumption. For the other in depth assessment a freshly cooked meal was chosen; Chicken meal. The Chicken meal consisted of chicken, rice, carrots, broccoli, cauliflower and a paprika sauce. The Chicken meal was produced in Norway. A freshly cooked meal is just pre-treated at the industry and requires cooking preferably in the microwave before consumption. The six meals that were assessed by a screening methodology were: Meal 1 pasta, vegetables and tomato sauce, Meal 2 lamb, rice, and vegetables, Meal 3 smoked sausage and bacon, mashed potatoes and kale, Dish 4 coated chicken fillets, Dish 5 souvlaki (chicken fillets) and Dish 6 pasta, cheese and vegetables. The functional units were one packed and consumed meal at the household. The whole life cycle was included in all assessments (i.e. agriculture, production, retailer, household, packaging production, waste management as well as all transports involved). The environmental categories assessed were for the in depth assessments; eutrophication, acidification, global warming potential and primary energy consumption and for the screening assessment the result was given in global warming potential.

The decrease in wastage from 20% to 5% at the retailer gave a large decrease in environmental impact. For example for the Hunter's meal the primary energy requirements decreased with 13% and for the Chicken meal the contribution to eutrophication and acidification decreased with 12%.

The result from all meals showed that the production of the ingredients was the step which contributed most to the environmental impact independent of impact category. It was the animal originated ingredients that made up the largest contribution.

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# 1. Background

This delivery (D7.8) forms part of Workpackage 7: Final assessment of the newly developed meals within the EU-project Double Fresh. Double Fresh is the acronym for the project titled: 'Towards a new generation of healthier and tastier ready-to-eat meals with fresh ingredients'. The overall aims for Double Fresh are to raise the quality of ready-to-eat meals. Such meals could:

- be fresher, tastier and more appealing
- be healthier and safe
- have a longer shelf life for more viable food business

The name Double Fresh comes from that two concepts of meals were developed within the project. The first one is a ready-to-eat meal with fresh food that is precooked/pretreated. The consumer just needs to heat it up. The other concept is named freshly cooked. These types of meals are not precooked. The meal is cooked in the microwave by the consumer just before eating.

This delivery is part of the final assessment of the new meals and it consists of an environmental assessment of the meals developed within Double Fresh. The overall aim connected with the environmental assessment is the time of shelf life. A longer shelf life often means less wastage of product. The goal of Double Fresh is to extend the shelf life of the meals from 5 to 9-14 days then the waste at the retailer would decrease to around five percent. In the Netherlands today the wastage of ready meals can be as high as 20% depending on the dish. To find out the environmental improvements by this decrease of wastage of the product at the retailer, environmental assessments of the meals in a life cycle perspective was required.

The work was conducted in three parts. Two in-depth life cycle assessment, one double fresh meal and one freshly cooked meal, as well as screening assessments of the other six meals developed and evaluated within the Double Fresh project. The outline of the report is: first, the goal and scope of the two in-depth life cycle assessment are presented. Then the case study of the Hunter's meal is presented including inventory, results and discussion. This is followed by the case study of the Chicken meal including inventory, results and discussion. After that follows the screening assessment of the six meals, including goal and scope, inventory, results and discussion. Finally, an overall discussion and conclusions ends this report. But, next follows a brief description of the environmental life cycle assessment methodology.

## 2. Brief Life Cycle Assessment methodology

The performance of a Life Cycle Assessment (LCA) is divided into four main parts: Goal and scope definition, Inventory analysis, Impact assessment and Interpretation of results. In the goal and scope definition, the system to be studied and the purpose of the study is defined. System boundaries are chosen, preferably reflecting the boundary between the natural and the technical system under study, that is, normally starting with extraction of raw materials and ending with some sort of waste treatment. The inventory analysis consists of gathering of data about the resource use, energy consumption, emissions and products resulting from each activity in the production chain. All in- and outflows are then calculated on the basis of a unit of the product called the functional unit. The choice of this unit should represent the function of the product. From some activities, more than one product may be the outcome. In such cases, the total environmental impact is often divided between the main product and by-products, a procedure known as allocation in LCA methodology. Allocation is based on the most relevant relationship between the main product and by-products in each case, e.g. mass, energy content or economic value. Another approach is to include the by-products in the system and separately assess another production system for this product, which can then be subtracted from the original system in order to obtain results for the main product. This latter approach is called system expansion and is recommended by ISO.

The first result of an LCA is a matrix of inventory results, where the calculated values for each phase of the life cycle and also the total values are presented for a number of categories of substances like resources from ground, resources from water, emissions to air, emissions to water and products. In order to simplify this table and to get an idea of what kind of environmental impact the emissions cause, characterisation methods are used which weight together all emissions causing for example global warming, acidification, toxicity, eutrophication, photochemical ozone formation and stratospheric ozone depletion. Characterisation together with qualitative assessment of types of environmental impact that cannot be characterised is called impact assessment. Qualitative assessment means that when no reliable method to quantify a category of environmental impact exists or data is lacking, it can be assessed qualitatively. Normalisation and Weighting are optional steps aiming at relating the environmental impact of the studied activity to other activities in society and comparing the different types of environmental impact to each other, respectively. Whether these steps are performed or not depends on the goal and scope of the study. After impact assessment and eventually normalisation and weighting is completed, the interpretation of results and identification of key figures and initial assumption and a sensitivity analysis follows to finalise the LCA. In the sensitivity analysis, key figures are varied and the dependence of the results on certain data is analysed in relation to the quality of those data. There are many good handbooks explaining step-by-step how to perform an LCA (Baumann & Tillman 2004, Berlin 2003, Hauschild & Wenzel 1997, Wenzel et al.1997). The software used for the LCA calculations was SimaPro 7 (Pré Consultants bv., 2008).

### **3. Goal and Scope for the in-depth assessments; Hunter's meal and Chicken meal.**

#### **Goals**

The overall aim of the in-depth assessments is to quantify the environmental improvement potential possible by decreasing the wastage of ready meals at the retailers from 20% to 5%.

Specific objectives related to the overall aim are:

- to assess the environmental impact of one ready-to-eat meal.
- to assess the environmental impact of one freshly cooked meal.

#### **Description of products**

The ready-to-eat meal chosen for the assessment was Hunter's meal. The Hunter's meal consists of pork, mashed potatoes, mushroom sauce and carrots. It is a meal produced by Snellman Kokkikartano Oy in Jacobstad in Finland.

The freshly cooked meal chosen for the assessment was a Chicken meal. The chicken meal consists of chicken, rice, carrots, broccoli, cauliflower and a paprika sauce. The meal has no producer today but was developed for the Norwegian market by Nofima in cooperation with the companies Nortura BA and Fjordland AS.

#### **Functional unit**

In a life cycle assessment a unit is chosen to which all the environmental calculations are related to. The functional units chosen for these two studies were:

- one packed Hunter's meal consumed at a household in Finland and
- one packed Chicken meal consumed at a household in Norway.

#### **System boundaries**

The studies include the life cycle steps (illustrated in figure 1 and 2). The first step is the production of the raw materials (the agricultural phase) required for the ingredients' production. The data used for the agricultural step includes all farming activities and its inputs of feed, fertilisers and energy sources in a life cycle perspective. This step is followed by the production of the ingredients. After that the meal is composed and pre-treated at the ready meal manufacturing. Then the meal is transported to the wholesaler grocery which is followed by the retailer, which is illustrated by the retailer box in figure 1 and 2. Finally the meal reaches the consumer. All transports required for raw materials, ingredients and meal are also included. Production of packaging as well as the waste management of the packaging material is included as well.

#### **Environmental impact categories**

The environment can be assessed in a number of ways. Including in life cycle assessment methodology the impact categories to choose among are for example; energy, water, land use, global warming, photo oxidant ozone formation, ozone depletion, acidification, eutrophication and toxicity. It is rather unusual to include all impacts. In fact, today many clients are just interested in global warming. But, to get a better picture of the environmental impact it is

preferable to include some more impacts. The hard thing is to select the ones giving the most information to get an environmental picture of the product under study. The categories chosen for the quantitative assessment in this study are; climate change, energy use, acidification and eutrophication. The categories specified include the key parameters for the environmental impact of food production identified by Mattsson (1999). The key inventory parameters are nitrous oxide, methane, ammonia and energy-related emissions. The water use is a category that has been put forward the last years within the LCA community. Nevertheless, it is not included in this study as the countries Finland and Norway do not have a water problem. The category of land use is also an important issue when it comes to food production but for Norway and Finland this is not a problem. Both countries are sparsely populated with large areas of wilderness. Therefore, the area of land is not a problem. To exclude the impacts of water- and land use was a decision made although, we were aware of that the imported ingredients may come from areas where these impacts are of importance. Another fact is that it would have been unrealistic to include water and land use of all the ingredients within the budget of the project. The references of the equivalence factors for the chosen environmental categories used in the calculations were; IPCC (2007) for climate change, EDIP/UMIP 97 (1997) for acidification and EDIP/UMIP 97 (1997) for eutrophication. For the calculations of primary energy production no equivalence factors were required.

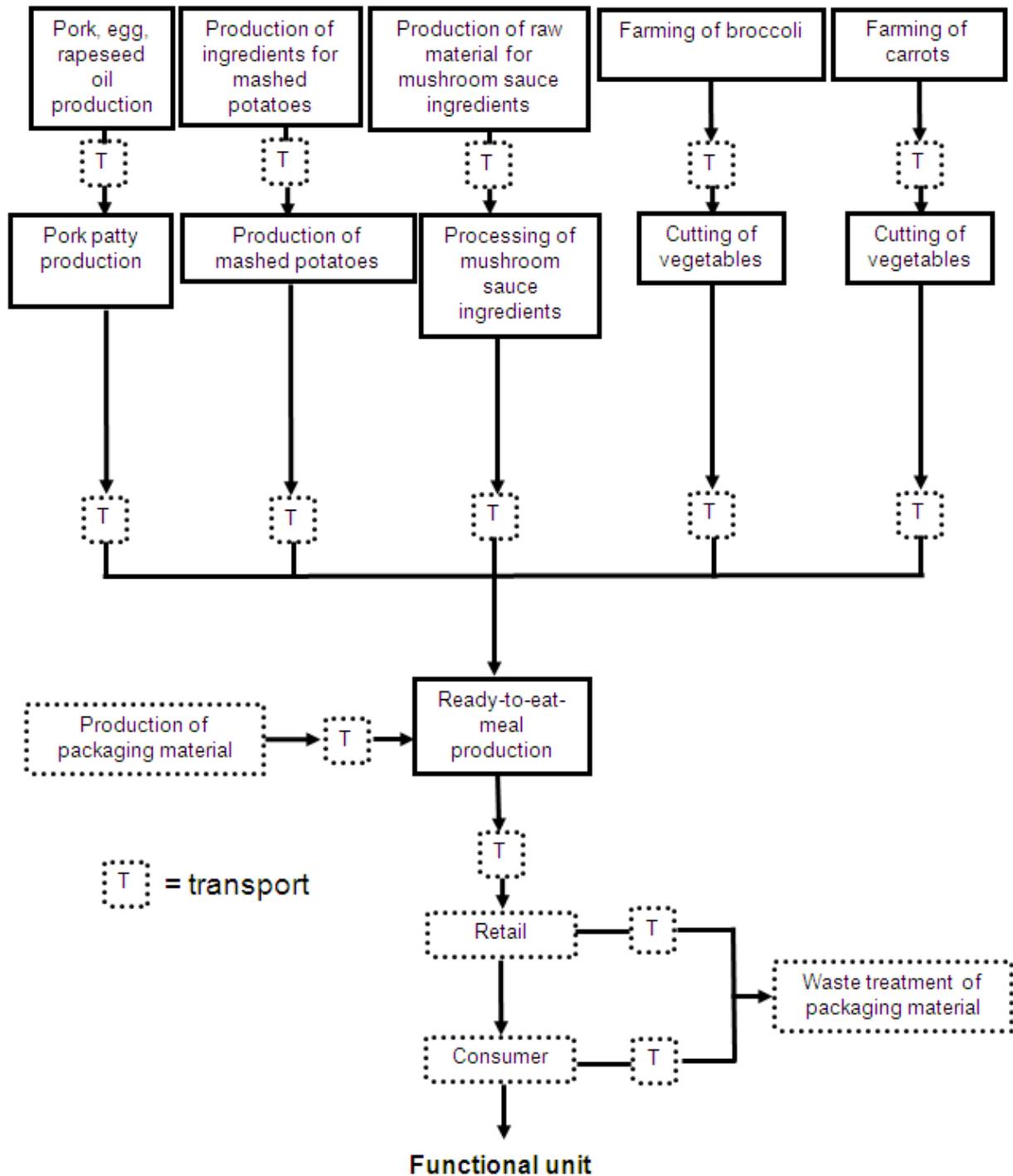


Figure 1. The system under study for Hunter's meal. T is an abbreviation for Transport. For steps illustrated with boxes with dotted lines no specific data inventory has been fulfilled instead the data is based on literature data or data found in a databases

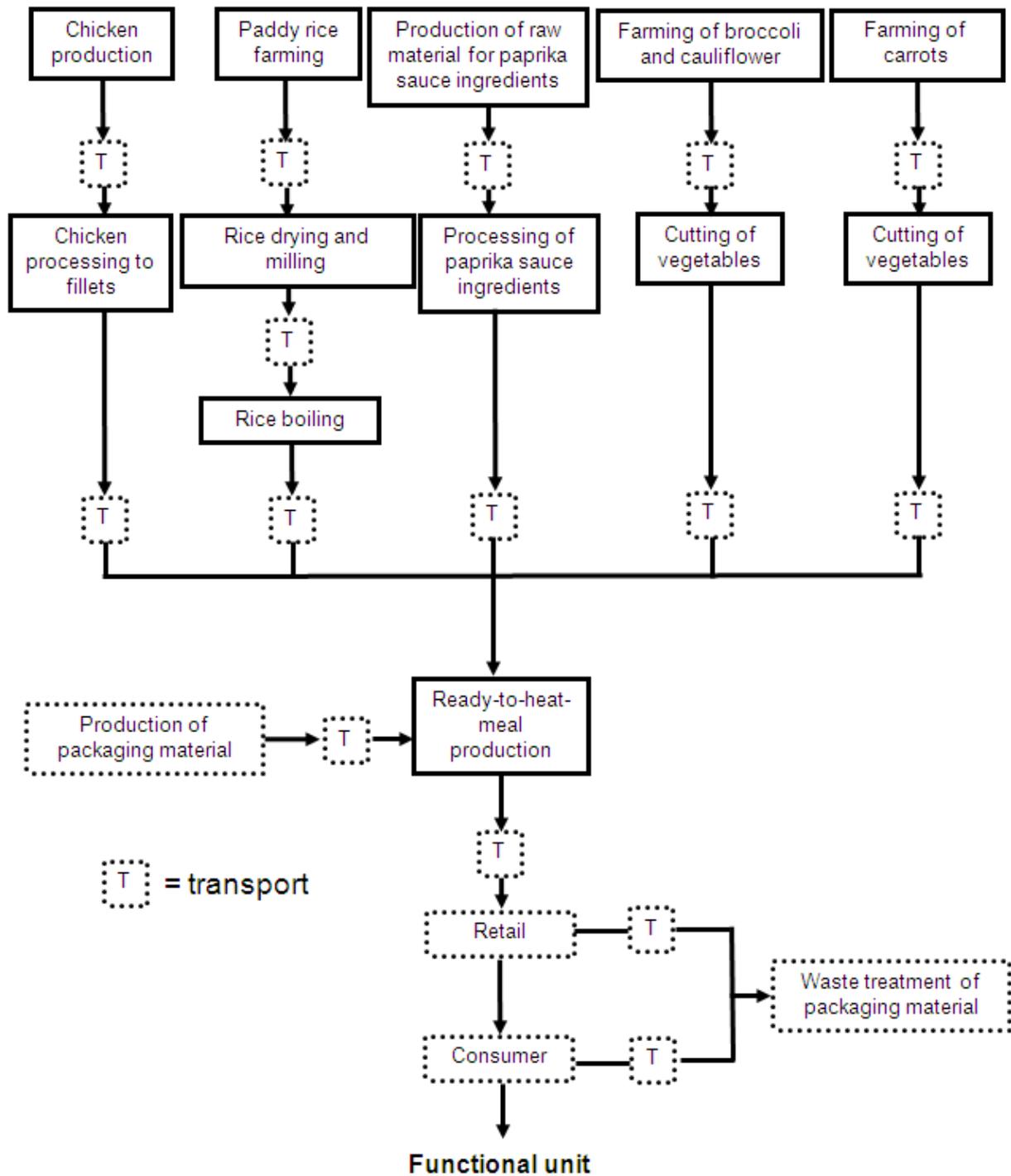


Figure 2. The system under study for the Chicken meal. T is an abbreviation for Transport. For steps illustrated with boxes with dotted lines, no specific data inventory has been fulfilled instead the data is based on literature data or data found in a databases

## **Data sources and quality of data**

Data used in the study comes from inventory by personal visits, personal contacts by telephone and email, studies performed by SIK, data collected from databases as well as literature data. The specific method chosen for the each data set is described in the Inventory section.

For a meal there are plenty of data that has to be gathered as there are several ingredients. It was not feasible to make inventories for all ingredients by personal visits which would have been the best for the quality of data. Therefore, our strategy for those ingredients was to use data sets as similar as possible to the ingredients used in the meal. For example when data for the specific country from where the ingredients were imported was missing in literature or databases the energy mix for that country was used with the data set that was available. We used data sets from studies performed by SIK and other sources with good data history before literature data and data base data with a scarce description of the data.

## **Allocation and system expansion**

When there is more than one product produced in the same production step or activity an allocation is required to share the environmental impact between the products. According to the ISO standard (ISO 2006a and ISO 2006b) for LCA, system expansion is the preferred method to avoid allocation. System expansion means that the system boundary of the product will be expanded to include both of the products. This is not always feasible due to the projects limits in time and costs. In some cases allocation is required. According to the ISO standard a physical allocation is preferable before an economical allocation. When it comes to foods a physical allocation is not always achievable due to that sometimes the by-products is produced in larger quantities as for example whey in cheese production. The economical allocation can be a solution. In fact economical allocation is the most common method used within the food sector. But, when possible system expansion is the preferable method.

This study of meals consists of several ingredients and therefore also consists of data from several sources. The data sets included mostly economical allocation but also system expansion and physical allocation.

## **Limits of the study**

The limits of the study are dependent of the projects aim and limits in time and costs. Limits according to time, machinery, buildings and infrastructure, personnel as well as waste of ingredients and products are described below.

### *Time*

This study was supposed to be a study of the environmental impacts by the life cycle of the meal today. Therefore, the data used for the study represents the most updated data sets as possible. However, as data from different sources where used the age of data varies.

### *Machinery, buildings and infrastructure*

The infrastructure is included in the background data of the data sets originated from the databases of Ecoinvent (2007) including packaging material, energy and transports. Machines, buildings and infrastructure were not included in the other data sets used in the study.

### *Personnel*

The commuting, lunches and working clothes for the personnel were not included in the calculations.

### *Waste of products and ingredients*

Waste of products and ingredients at the household was not included in the study. Due to that the aim of the study was to find out the decrease in environmental impact by the waste decrease at the retail sector.

### *Ingredients*

The production of mushrooms, paprika, spices (except for salt), antioxidants, aroma, fatpowder, yeast extract, modified starch glucose and colour were not included in the study because of lack of data. Those ingredients are used in small quantities and are therefore not considered to make large contributions to the environmental impact.

## **4. Hunter's meal**

Hunter's meal consists of pork, mashed potatoes, mushroom sauce and carrots. The goal and scope of the environmental assessment was described in the section above. On top of that Snellman Kokkikartano Oy wanted us to find out the consequences of the environmental impact of the meal if the carrots were replaced with broccoli. This section describes the inventory of data, the result of the environmental assessment as well as a result discussion.

### **Inventory of data**

Inventory of data regarding every phase in the life cycle includes use of raw material, energy, spoilage, emissions and waste management. In this chapter inventoried data regarding the life cycle of the Hunter's meal is described quantitatively alternatively referred to literature and other data sources.

### **Energy**

For electricity use in Finland data for Finland's electricity mix including imports has been used (based on data from Ecoinvent, 2007), since no specific electricity production has been stated. For the fossil fuels emissions from the whole life cycle are included. Data of emissions from production and use of energy has been gathered from the database Ecoinvent (2007).

### **Ingredients**

The ingredients and the amount of each used in the Hunter's meal is listed in table 1. This is followed by a description of each ingredient.

**Table 1. Ingredient composition of the Hunter's meal**

| <b>Ingredient</b>                         | <b>g ingredients</b> | <b>g in meal<br/>(prepared)</b> |
|---|----------------------|---------------------------------|
| <b>Meat patty</b>                         |                      | <b>100</b>                      |
| Pork fillet                               | 80                   |                                 |
| Bread crumbs                              | 16                   |                                 |
| Rapeseed oil                              | 11                   |                                 |
| Egg                                       | 2                    |                                 |
| Water                                     | 2                    |                                 |
| <b>Mashed potatoes</b>                    |                      | <b>175</b>                      |
| Potatoes                                  | 138                  |                                 |
| Water                                     | 37                   |                                 |
| Cream                                     | 11                   |                                 |
| Whole milk powder                         | 4                    |                                 |
| Butter                                    | 3                    |                                 |
| Salt                                      | 1                    |                                 |
| <i>White pepper*</i>                      | 0,02                 |                                 |
| <b>Mushroom sauce</b>                     |                      | <b>45</b>                       |
| Water                                     | 22                   |                                 |
| Vegetable fat and dairy product blend     | 17                   |                                 |
| <i>Mushrooms*</i>                         | 13                   |                                 |
| Seasoning for mushroom sauce              | 5                    |                                 |
| Butter                                    | 2                    |                                 |
| Onion                                     | 1                    |                                 |
| Modified potato starch                    | 1                    |                                 |
| Meat stock                                | 0.3                  |                                 |
| Salt                                      | 0.0                  |                                 |
| <b>Vegetables</b>                         |                      | <b>30</b>                       |
| Carrots                                   | 30                   |                                 |
| <b>OR</b>                                 |                      |                                 |
| Broccoli                                  | 30                   |                                 |
| <b>Whole meal</b>                         |                      | <b>350</b>                      |
| <i>*data not included in calculations</i> |                      |                                 |

**Meat patty*****Pork meat***

Fat and bone free pork meat is approximated as the pork portion of the Hunter's meal. The pig farms from where the data is extracted are located in Sweden and a report from 2002 is used for the in-data (LRF, 2002).

***Bread crumbs***

The bread crumbs are assumed to consist of 95% wheat flour and 5% salt (NaCl).

Data on wheat flour is from a study previously performed by SIK regarding production in Western Sweden (Cederberg et al., 2008). Sodium chloride (salt) data used is an average of European production (Ecoinvent, 2007).

### ***Rapeseed oil***

Data from a Swedish production of rape seed oil from a previously performed project at SIK has been used for this fraction of the Hunter's meal (SIK, 2009).

### ***Egg***

Data from Swedish egg production representing two farms has been used for the egg portion in the pork product (Sonesson et al., 2008).

### ***Water***

Ecoinvent data on tap water has been used, representing a European average (Ecoinvent, 2007).

## **Mashed potatoes**

### ***Potatoes***

Data regarding the potatoes used in the mashed potatoes comes from a study previously performed by SIK (SIK, 2009) representing four potato farms in the south-east province Östergötland in Sweden. The production years studied was 2000 and 2001.

### ***Water***

Ecoinvent data on tap water has been used, representing a European average (Ecoinvent, 2007).

### ***Cream***

The data for cream used in the mashed potatoes is approximated with an average from two dairies. Cream produced in a dairy of whole milk powder production and in a skim milk powder production. Both dairies are located in Sweden. Data on milk production at the farm level comes from a previously performed LCA study at SIK regarding milk production in Norrland, the north region of Sweden (Cederberg et al., 2007). The agriculture practise for milk production in the Norrland region was assumed to be a good estimate of Finnish milk production depending on the similarities in climate between Norrland and the area around Jacobstad.

### ***Whole milk powder***

Data on the whole milk powder comes from a Swedish dairy. It is one of the dairies the cream is allocated from as previously mentioned. Data from the same study as for cream regarding milk production at the farm level was used for whole milk production as well (Cederberg et al., 2007).

### ***Butter***

An average data set of Western Europe butter production has been used for the butter. Data comes from a project previously performed by SIK, and represents production between the years 1998 and 2005 (SIK, 2009).

### ***Salt***

Salt data used is from European average production (Ecoinvent, 2007).

### ***White pepper***

White pepper is left out of the study due to lack of data regarding this spice.

## **Mushroom sauce**

### ***Water***

Database data on tap water has been used, representing a European average (Ecoinvent, 2007).

### ***Vegetable fat and dairy products-blend***

A blend of vegetable fat, lactose reduced cream and buttermilk were used as components in the mushroom sauce. Exact data on composition has not been obtained. Therefore, an assumption has been made with 85% dairy products and 15 % vegetable fat. Data of vegetable fat was approximated with rape seed oil. The dairy products were approximated with 50% cream and 50% milk. Data on cream from milk powder production used, was based on Swedish dairies producing whole milk powder and skim milk powder. Milk data at the farm level is also the same as for the cream and whole milk powder (Cederberg et al., 2007).

### ***Mushrooms***

Mushrooms have been left out due to lack of information regarding this ingredient.

### ***Seasoning for mushroom sauce***

The seasoning contains of modified starch (E1422/corn), milk powder, fat powder, spices (black pepper and onion), aroma (mushroom and cream), yeast extract, salt glucose and colour (E 150c). Data of modified starch was approximated with maize starch from an Ecoinvent process with the same name, produced in Germany, data for production year 1998 (Ecoinvent, 2007). The milk powder was assumed being whole milk powder and hence the same data as for the whole milk powder in the mashed potatoes was used. Data of milk production at the farm level was also the same as in the whole milk powder used in the mashed potatoes (Cederberg et al., 2007). Fat powder was left out due to lack of data. Data on black pepper was also absent, and hence onion has been used for the whole spice portion. Due to lack of data on mushroom the cream represented the aroma in the seasoning. Data on yeast extract, glucose and color was lacking and are hence treated as data gaps. Data of salt originated from an European average of salt extraction and refining (Ecoinvent, 2007).

### ***Butter***

The same data set for butter as in the mashed potatoes has been used (SIK, 2009).

### ***Onion***

Data of Swedish production of onion from a previously performed project at SIK has been used for the onion in the mushroom sauce (SIK, 2009).

### ***Modified potato starch***

Data of the potato starch used in calculations is of German origin and was found in the Ecoinvent database (Ecoinvent, 2007)

### ***Meat stock***

The meat stock was approximated with 50% potato starch and 50 % salt. The same potato starch as mentioned above has been used as data source (Ecoinvent, 2007). Data of salt came also from Ecoinvent (Ecoinvent, 2007).

### ***Salt***

The salt data used originated from the European average production (Ecoinvent, 2007).

## **Vegetables**

### ***Carrots***

The baby-carrots in the meal come from Belgium and are transported to Jakobstad by truck and boat. Due to lack of Belgian data of carrots production data from an ongoing study at SIK of Swedish carrots (Davis et al., 2009) were used. 30 % of the carrots were assumed to be farmed in peat and 70% in mineral soil. Phosphorous and pesticide use were left out in the study due to lack of data. But, the transportation from Belgium to Jakobstad was included.

### ***Broccoli***

Broccoli is not used in the current production but is evaluated as an alternative to the carrots used in the meal. The broccoli was assumed to be produced in Spain and data used for the broccoli comes from a study previously performed at SIK (Angervall et al., 2006).

## **Packaging**

### **Packaging material**

22 grams of CPET plastic is used for each Hunter's meal container. The plastic used in the calculations was polyethylene terephthalate, granulate, bottle grade and an injection moulding (Ecoinvent, 2007). In this data the previous steps in the production of plastic granulate are included. A plastic film on top of the container is also part of the packaging. This plastic is approximated with the same PET plastic due to the small amount used; 4.2 grams per packaging unit. 10 grams of carton is used as a secondary packaging. For this a solid unbleached board was used. All data was found in Ecoinvent (2007).

### **Waste management of packaging**

According to Swedish recycling statistics 30.5 % of all plastic is material recycled, and this fraction was used in the waste management here as well. Hence 69.5% of the plastic is incinerated. For the solid unbleached board solely incineration (no recycling) was assumed. Heat production for the district heating system in incineration was assumed to replace production of district heating (except for waste incineration) and electricity production. This replacement contributes to avoided production of other fuels in the district heating system. Emissions of environmentally harmful substances from incineration was taken into account, and hence it is not self-evident that the incineration causes an 'environmental gain'. Data from Ecoinvent (2007) and SIK's environmental database (2009) has been used for these calculations. Material recycling of plastics was treated as avoided production of average PP-plastic (the same plastic used as input in the packaging).

## Ready meal industry

The electric energy use at the factory was approximated to 800 000 kWh for the year 2009. An approximation of 30 % of the electric energy used at the processing facility attributed to the production of ready meals was used. The total production of ready meals in 2009 was approximated to 550 tonnes. Hence the electric energy consumption used in the calculations was per kg meal 0.44 kWh, and per 350 gram meal 0.15 kWh.

The fuel oil used at the factory was assumed to be light fuel oil, EO1, with the specific heat value of 9950 kWh/m<sup>3</sup> (ÅF, 2009). 35 000 litres of oil was used at the factory. Hence 0.064 litres of fuel oil was used per kg produced ready meal. The density of the fuel oil is 0.840 kg/litre (ÅF, 2009), consequently 0.05 kg fuel oil was consumed per kg ready meal produced. As a consequence 0.019 kg (0.022 liter) oil was needed for production of one 350 gram ready meal. This corresponds to 0.22 kWh per 350 gram meal (0.022\*9.950).

The estimated spoilage of ingredients and ready meals at the factory was 1 %.

## Transports

For all transports a truck with maximum load 40 tonnes and load factor 50 % has been used, based on Ecoinvent data (Ecoinvent, 2003). The same truck with refrigeration or freezing equipment has been used where appropriate, freezing equipment adds 22% operation on the truck and refrigeration adds 11%.

### Incoming transports

The pork is slaughtered at Granholmen, 5 km away from the processing unit and is transported to the industry by truck. Bread crumbs and eggs are from Oulu (Uleåborg) which is located 300 km from Jakobstad. Rapeseed oil is bought from Åbo and transported by truck, 450 km. The mashed potatoes are produced at a processing unit located 1 km from the ready meal factory. Incoming transports of ingredients to this location is inventoried and potatoes are from Jeppo, located 40 km from the industry, transported by truck. Cream, whole milk powder and butter used in the mashed potatoes are from Oulu (Åbo) and hence transported 300 km by truck. Salt is from Jakobstad and transported 2 km by truck.

The carrots are from Belgium and the distance from farm to processing in Jakobstad is assumed 2064 km (distance calculated between Brussels and Jakobstad, from [www.viamichelin.com](http://www.viamichelin.com)).

Since broccoli is not currently used in the production no transport distance was obtained. The transportation used was instead based on data from the broccoli study used as data source for this ingredient. The transport was assumed to be from Spain to Finland by truck and the distance used was 3867 km (Murcia-Jakobstad) according to [www.viamichelin.com](http://www.viamichelin.com). The vegetable fat and dairy products-blend, the modified potato starch and meat stock are all from Helsinki, the transport distance to Jakobstad is 500 km. The salt is from Jakobstad and the transport is 2 km. Butter is transported from Oulu (Uleåborg) (300 km) and the onions are from Turku (Åbo) (450 km).

## Wholesaler

The meal is stored approximately three days at wholesale and Finnish electricity mix is assumed being the energy source used. 0.05 MJ electricity is used per kg product for refrigerated storage for less than a week according to SIK Food database (SIK, 2009).

## **Retail**

The ready meal is assumed to be stored at the retailer for approximately six days. Energy consumption for refrigerators at the retailer is rather high due to open refrigerators. Data used comes from a study performed by SIK of energy consumption in retail stores; “short storage” is approximated to consume 0.2 MJ/kg chilled product (Carlsson & Sonesson 2000).

## **Household**

Assumed distance for transport from the retailer to the household is 7.81 km, and 59 % of all customers go by car when grocery shopping, the rest go by bus or walk, based on Orremo et al. (1999). The car used is a passenger car based on Ecoinvent (2007). No climate burden has been ascribed to walking or going by bus.

Energy consumption in the household is modelled with Finnish electricity mix with electricity import based on an Ecoinvent process from 2007. Heating in microwave oven and chilling in fridge is driven by electricity. Microwaving the meal for 3 minutes in 800 W was calculated to consume 0.04 kWh. The microwave power value used in the calculations was based upon a simplified assumption where the energy efficiency of the microwave oven as well as the energy required for cooling of the magnetrons are not included. However, the corresponding influence on the resulting response values is negligible as compared to the order of magnitude of the total energy consumption of the LCA result. Refrigerant storage for three days is approximated with a function derived from a study performed by SIK (Sonesson et al. 2003) where the average energy use for the refrigerators studied was 2.84 MJ/litre\*year. This function is accommodated by multiplying the volume occupied by the ready meal in the fridge (1150 ml) by three (to make up for the empty space in the fridge, which is thought to be 2/3 of the cabinet's volume). This number is multiplied by 2.84 MJ (which is the average energy consumption of a refrigerator per litre and year, as previously mentioned) and later multiplied by the days stored in refrigerator (expressed as fraction of a year).

## Results Hunter's meal

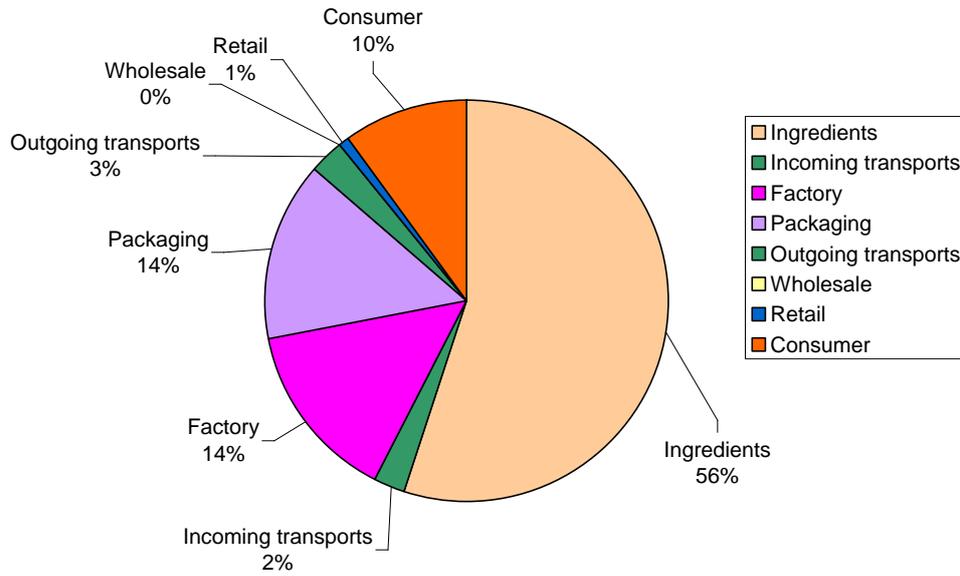
The environmental assessment results for the Hunter meal's in-depth LCA are presented below. A summary of result from the different impact categories with 5 % respectively 20 % spoilage at the retailer is presented in Table 2. After the overall results a more detailed picture of the different impact categories' results are presented in pie charts, with the percental environmental burdens presented per life cycle phase. In the pie charts the percental spoilage at the retailer was 5 %. The environmental burden caused by the ingredient production is presented per ingredient in the bar charts following. By reducing the retail spoilage the environmental performance of the meal can be lowered by up to 13%, which is shown in the table below for the category primary energy.

**Table 2. Summary of the overall results for the Hunter's meal regarding the impact categories studied.**

| Results for the Hunter's meal per environmental impact category | 5 % spoilage at retail            | 20 % spoilage at retail           |
|---|-----------------------------------|-----------------------------------|
|   | <u>kg CO<sub>2</sub>e/product</u> | <u>kg CO<sub>2</sub>e/product</u> |
| <i>Greenhouse gas emissions</i>                                 | <b>0.9</b>                        | <b>1.0</b>                        |
|   | <u>g NO<sub>3</sub>e/product</u>  | <u>g NO<sub>3</sub>e/product</u>  |
| <i>Eutrophication</i>   | <b>39</b>                         | <b>45</b>                         |
|   | <u>g SO<sub>2</sub>e/product</u>  | <u>g SO<sub>2</sub>e/product</u>  |
| <i>Acidification</i>  | <b>7</b>                          | <b>8</b>                          |
|   | <u>MJe/product</u>                | <u>MJe/product</u>                |
| <i>Primary energy</i>   | <b>13</b>                         | <b>15</b>                         |

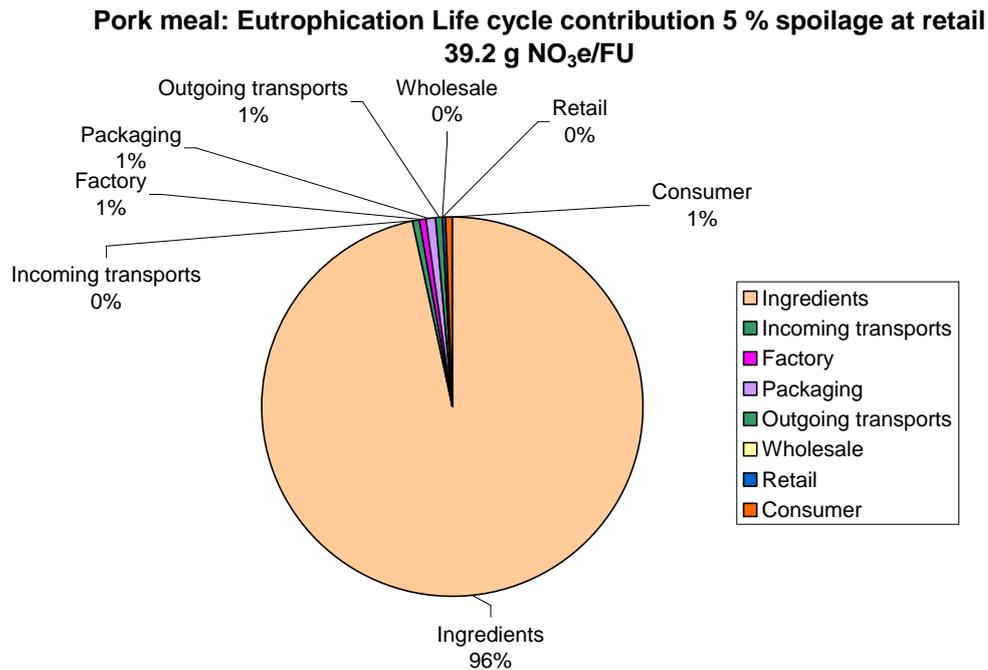
The following pie charts illustrate the different life cycle steps of the Hunter's meal's contribution to the environmental impact. Figure 3 illustrates the global warming potential, figure 4 the contribution to eutrophication, figure 5 the category of acidification and figure 6 the consumption of primary energy.

**Pork meal: GWP Life cycle contribution 5% spoilage 0.9 kg CO<sub>2</sub>e/FU**



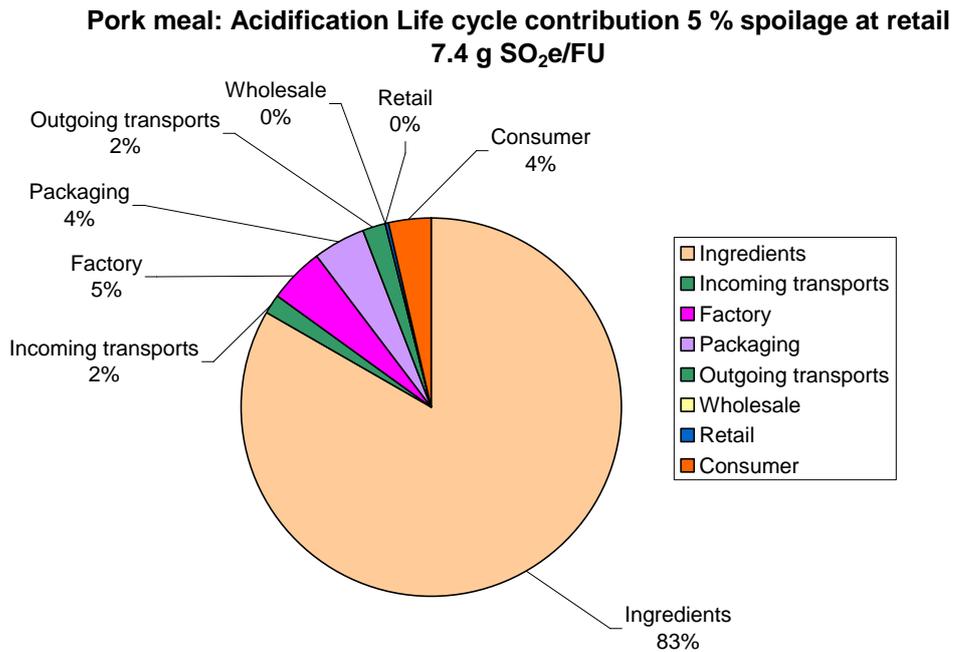
**Figure 3. Greenhouse gas emissions for the life cycle of the Hunter's meal.**

The ingredients in the Hunter's meal stand for more than half of the climate gas emissions caused by the meal's life cycle activities. The packaging contributes with 14 %, these emissions are primarily caused by the plastic production for the polypropylene container that the meal is packed in. The factory, i.e. the meal assembly, plays an important role in the Hunter's meal's life cycle; with a figure of 14%. Transports to and from the meal assembly contribute with 5% of the life cycle emissions, and this figure would be higher if two-way distances instead of one-way distances for the transports were used. The consumer phase contributes with 10 %. The dominating factor in the consumer phase is the car transport from retail to household.



**Figure 4. Eutrophication potential for the Hunter’s meal’s lifecycle**

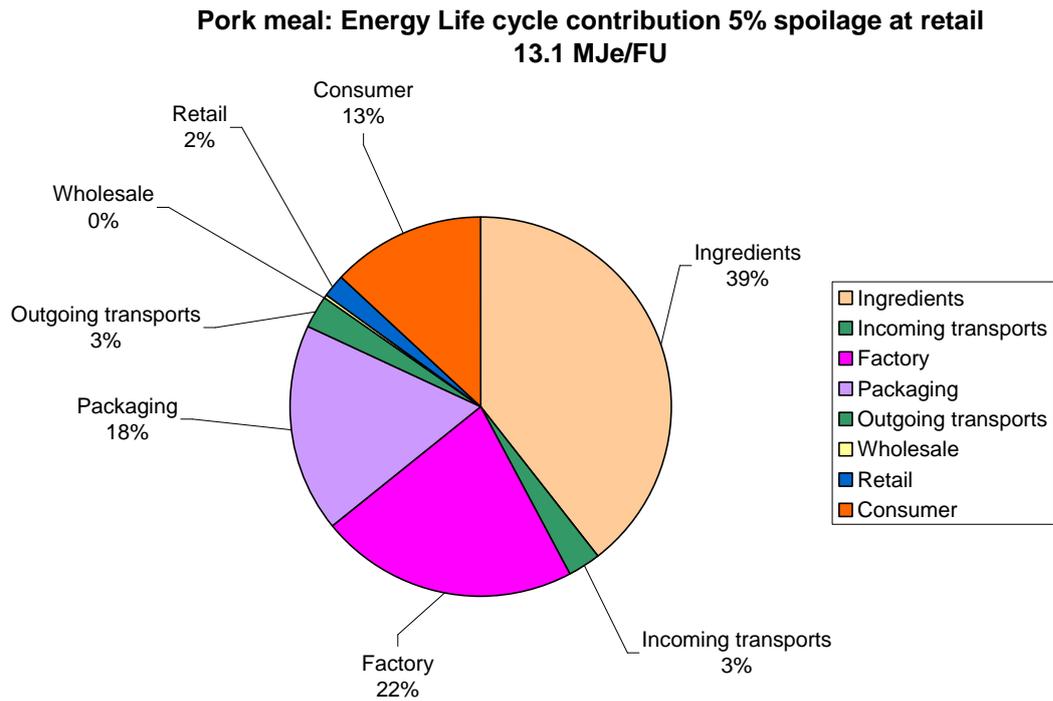
As eutrophication is an impact category closely related to the farming stage it is no surprise that it is the steps of ingredient production that contributes with 96%. Eutrophication is caused by nutrient leakage (nitrogen and phosphorous) that ends up in lakes and seas contributing to excessive algal blooms often followed by oxygen deficiency (because of all the extra biological material that has to be biodegraded) which in turn affects the whole water ecosystem by for instance fish death. An important source for the nutrients is the fertilisers (both production and spreading) as well as the manure spread on the fields. Burning of fossil fuels also emits nitrogen oxides, which have an eutrophication effect and this is the primary source for eutrophication in the other life cycle phases.



**Figure 5. Acidification potential for the Hunter’s meal’s life cycle**

Acidification is to a large extent caused by burning of fossil fuels, especially coal. The nitrogen oxides and sulphur oxides formed from combustion of the fossil fuels are the chemical compounds primarily responsible for this environmental impact. Considering diesel versus gasoline more acids are formed from combustion of diesel, because the nitrogen oxides from diesel combustion are harder to break down in the catalyst in a car. Another input into the acidification category is agriculture. The main part of the acidification related to agriculture comes from handling of manure. The storage and spreading of pig manure cause emissions of ammonia to air. This ammonia starts a nitrification process in the soil which is acidifying (LRF, 2002).

As can be seen in the chart a major part of the acidified compounds are attributed to the ingredient production for the Hunter’s meal; 83% of the total acidification from the Hunter’s meal’s life cycle. Combustion of fossil fuels is an activity present in all life cycle phases, but for the agriculture it is biological processes that cause most of the acidification. Acidification from ingredient production is derived both from the vegetables and meat.

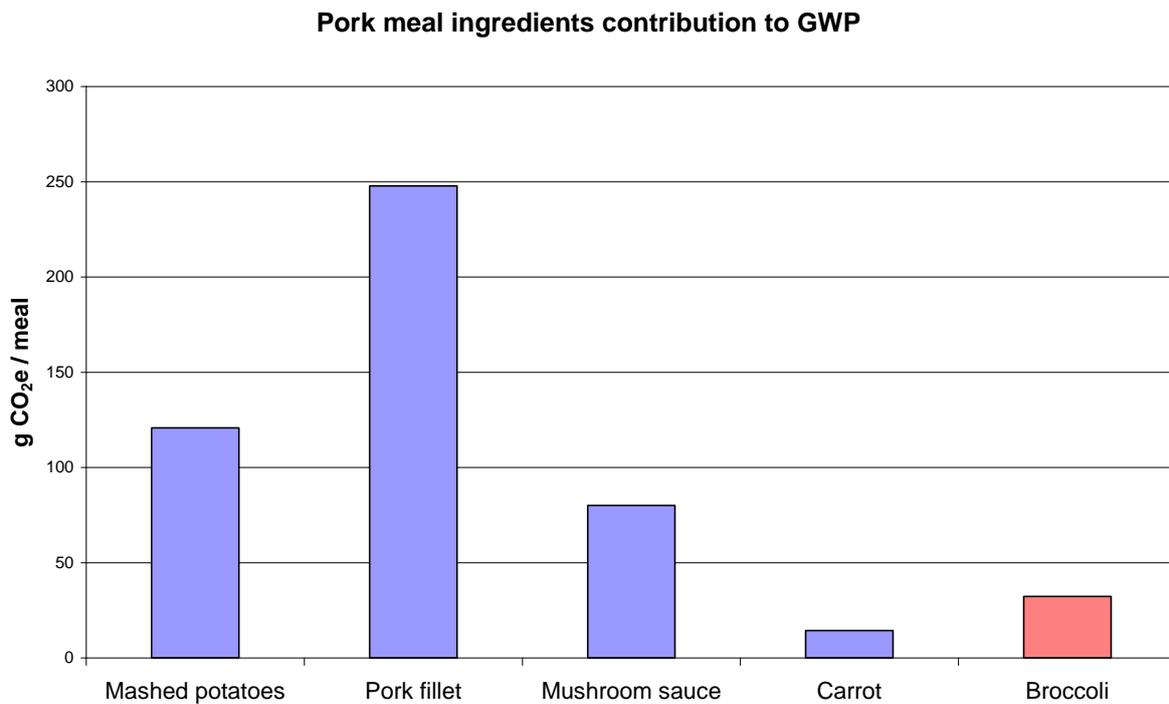


**Figure 6. Primary energy use for the Hunter's meal's lifecycle**

The primary energy use in the life cycle is shared quite equal between the ingredient phase and the packaging and factory phases together. The energy use is somewhat coupled to the climate gas emissions, with the difference that the stages requiring only electric energy (not necessarily based on fossil fuels) as for example the meal assembly, become more visible when assessing energy use (since this electricity does not cause climate gas emissions in the same extent as burning of fossil fuels).

## Ingredient results

For all the environmental categories considered was the production of ingredients the main contributor of the steps in the life cycle, see figure 3, 4, 5 and 6. Therefore, in this part of the result presentation we have chosen to concentrate on the ingredients. Figure 7, 8, 9 and 10 illustrates how much each of the ingredients contributes to respectively environmental impact. The ingredients are presented in weight order in each figure, the ingredient with largest proportion in the meal is presented to the left, and the amounts are descending to the right.

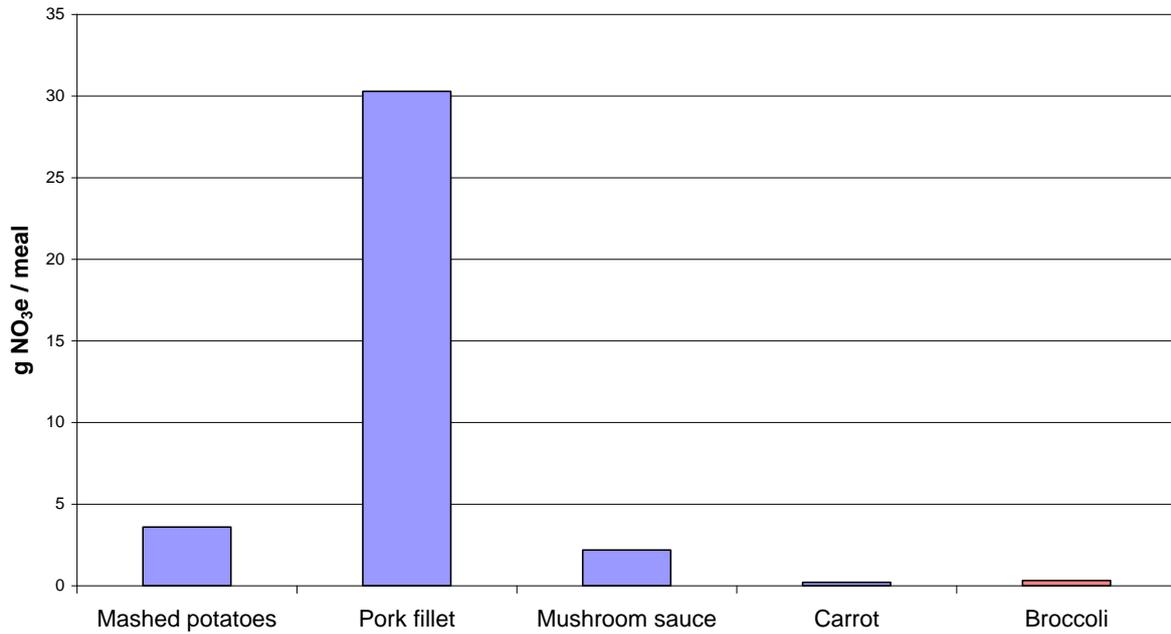


**Figure 7. Greenhouse gas emissions for production of ingredients for the Hunter's meal**

The main part of the GWP assigned to the ingredients comes from the pork production. The reason is the large amount of feed the pigs requiring. The high figures for the mashed potato and mushroom sauce were caused by cream, butter and whole milk powder used in both the mashed potatoes and the mushroom sauce. All these ingredients are animal originated. The cow cause extensive emissions of methane from digestion of feed and also dinitrogen monoxide from the feed production system itself make a large contribution.

The Swedish carrot causes somewhat less climate gas emissions than the broccoli, which is transported from Spain by truck, which increases the climate gas emissions from this ingredient. The carrot's farming phase also causes less negative environmental impact than the Spanish broccoli farming. However, replacing carrots with broccoli, in our judgement is OK due to that the difference in result between the two is minor.

### Pork meal ingredients contribution to eutrophication

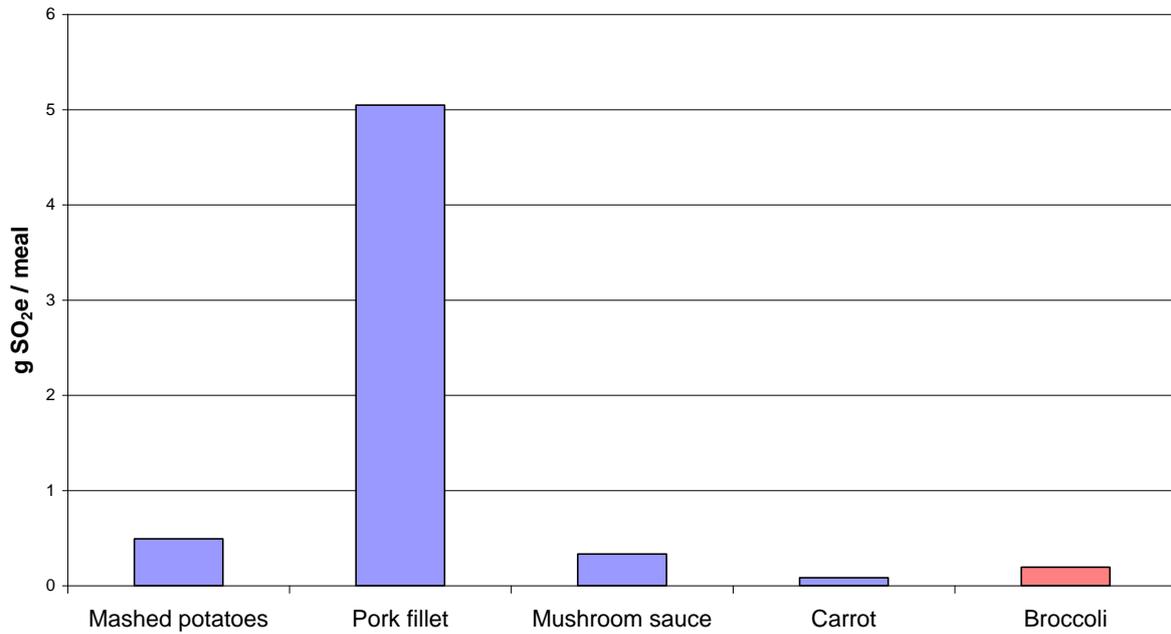


**Figure 8. Eutrophication potential caused by the ingredients in the Hunter's meal**

As previously mentioned the eutrophication is mainly caused by farming practise. Animal production has a higher impact compared to vegetables since the animals require large amounts of feed when reared. The farming of feed cause eutrophication through the fertilising compounds nitrogen and phosphorous that are spread on the fields and not thoroughly absorbed by the soil, but rinsed away to nearby waters by rainfall. Vegetable ingredients do not require as much farming activity as do animal products and hence these ingredients have less contribution to the eutrophication.

To change from carrots to broccolis equal to the environmental category of eutrophication.

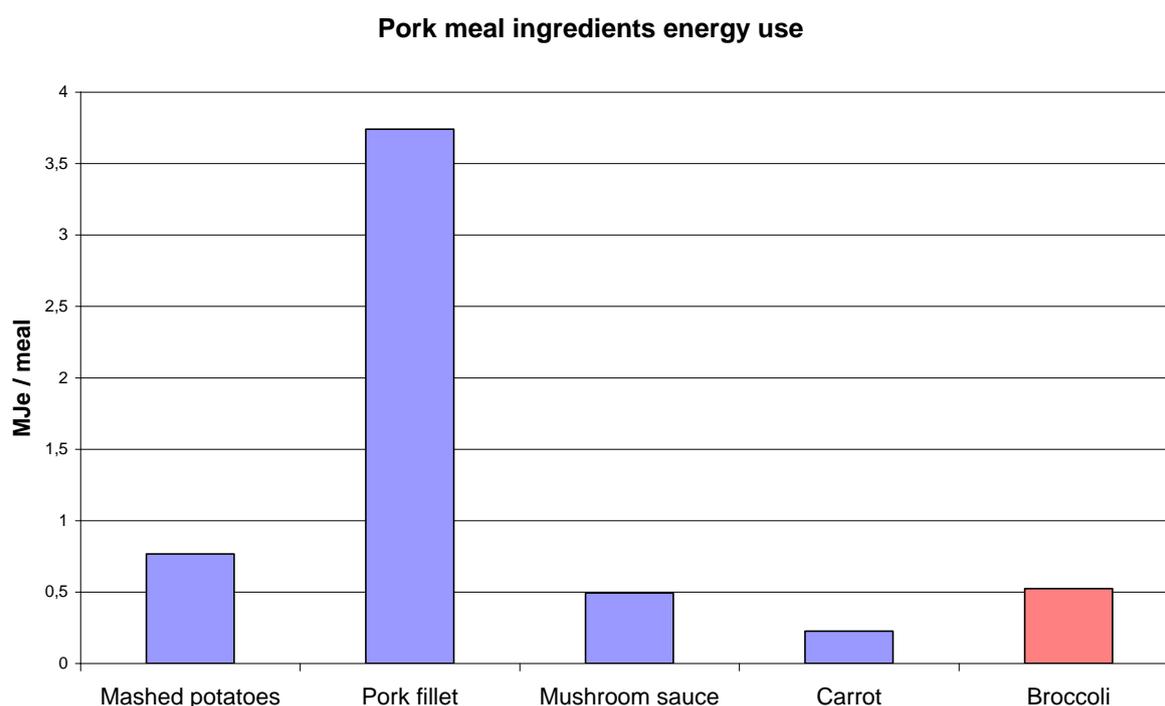
### Pork meal ingredients contribution to acidification



**Figure 9. Acidification potential caused by the ingredients in the Hunter's meal**

For the acidification the same relationship as for the GWP and eutrophication is true; animal products cause more acidification than do vegetable products. The sulphur oxides emitted are primarily caused by combustion of fossil fuels and the pork production overshadows the other ingredients since there are many underlying chains for this ingredient.

Changing carrots for broccoli is similar for the environmental category of acidification.



**Figure 10. Primary energy use for production of the ingredients in the Hunter's meal**

The primary energy use is largest for the pork fillet, because of the big inputs required in this farming system. Energy use for carrot production is the lowest of these ingredients depending on a very efficient farming system in Sweden.

Broccoli got a higher consumption of primary energy than the carrots. It is due to the truck transportation of broccoli from Spain and also a higher energy consumption in broccoli farming compared to the carrot farming. Nevertheless, in our judgement it is OK to change the carrots for broccoli in the meal as the difference between the two were not that high.

## Discussion Hunter's meal

The ingredient production is the dominating lifecycle phase for the Hunter's meal. This is true for all impact categories but not as apparent in the primary energy use results. Here the packaging and factory are also important phases. Looking at the environmental impact of the ingredient production, regarding all impact categories evaluated it is clear that it is the pork that causes the main emissions/influence. Animal production systems need more input than vegetable systems, since the animals need feed to grow to slaughter size and the conversion of vegetable feeds to meat involves losses, i.e. significantly more energy protein in feeds are needed to produce a certain amount of energy and protein in meat.

The feed production requires large areas of arable land, and from this land the soil leakage of e.g. dinitrogen monoxide (N<sub>2</sub>O) impacts the climate extensively. Furthermore production of inorganic fertiliser is an energy intense process that contributes both in the production (CO<sub>2</sub>-emissions and N<sub>2</sub>O-emissions) phase and in the farming phase (as the nitrogen fertilisers amplify the leakage of N<sub>2</sub>O from the fields, and also by CO<sub>2</sub>-emissions from the fertiliser spreading where diesel is used for the tractors). The animals' feed digestion also causes large

emissions of methane (except for rearing of chickens and pigs). Manure from pig production also causes methane emissions, since methane is formed during the storage of manure.

The Hunter's meal's assembly plant's climate gas emissions (14% of the life cycle emissions) are high in comparison with the Chicken meal (next section), where less than 1% is related to the meal assembly. The figures are however not entirely comparable since the energy use for the Hunter's meal is an inventoried number and the figure for the chicken meal is based on another study regarding ready meal production, and is hence not specifically inventoried.

The reason for the climate burden associated to the assembly factory is the large amount of oil used and the electricity consumption. To decrease the environmental burden from the energy is a suggestion to replace the fossil oil with some kind of bio fuel or gas generated from household wastage incineration. For the electricity a suggestion is to change to green labelled electricity mix. By choosing more cellulose products or biopolymers instead of fossil plastics as packaging material the climate gas emissions related to the packaging would be significantly lowered.

## 5. Chicken Meal

The Chicken meal consists of chicken, rice, carrots, broccoli, cauliflower and a paprika sauce. The goal and scope of the environmental assessment was described above. This section describes the inventory of data, the result of the environmental assessment as well as a result discussion.

### Inventory of data

Inventory of data regarding each phase in the life cycle includes use of raw material, energy, spoilage, emissions and waste management. In this chapter inventoried data regarding the life cycle of the chicken meal is described quantitatively alternatively referred to literature and other data sources.

### Energy

For energy use in Norway data for Norwegian electricity mix (mainly hydro power) including imports has been used (based on data from Ecoinvent, 2007), since no specific electricity production has been stated.

For the fossil fuels emissions from the whole life cycle are included. Data for emissions from production and use of energy has been gathered from the database Ecoinvent (2007).

### Ingredients Chicken Meal

The ingredients and the amount of each used in the Chicken meal is listed in table 3. This is followed by a description of each ingredient.

**Table 3. Ingredient composition of the chicken meal**

| <b>Ingredient</b>                                    | <b>g ingredients</b> | <b>g in meal (prepared)</b> |
|--|----------------------|-----------------------------|
| <b>Chicken fillet marinated in lingonberry juice</b> |                      | <b>130</b>                  |
| <b>Rice</b>  |                      | <b>100</b>                  |
| <b>Paprika sauce</b>                                 |                      | <b>100</b>                  |
| Cream  |                      |                             |
| Milk   |                      |                             |
| Paprika  |                      |                             |
| Rape seed oil  |                      |                             |
| Leek   |                      |                             |
| etc. ( <i>Ingredients are confidential</i> )         |                      |                             |
| <b>Vegetables</b>                                    |                      | <b>140</b>                  |
| Broccoli florets                                     | 50                   |                             |
| Cauliflower florets                                  | 50                   |                             |
| Carrot slices  | 40                   |                             |
| <b>Spices</b>  |                      | <b>1</b>                    |
| <i>Black pepper*</i>                                 | 1                    |                             |
| <b>Whole meal</b>                                    |                      | <b>470</b>                  |

*\*data not included in calculations*

## **Chicken**

Data on farming of the chickens for the chicken fillets is based on an LCA on Swedish chicken production in 2005 performed by SIK (Cederberg et al., 2009). Nitrogen use and leakage is added to make results in various impact categories possible to achieve. The farming takes place near Rakkestad in Østfold in Norway, the city location is used to calculate distances, but the data on farming is solely taken from the study on Swedish chicken production. Chickens are transported by truck from the farm to Rakkestad and Elverum, where slaughtering occurs. Data on slaughtering comes from LRF (2002). Processing to chicken fillets is based on data from the processing plant in Haerland, located 25 km from the slaughtering in Rakkestad and 200 km from Elverum (Personal communication with Tore Næss, Nortura, 2009). The processed chicken fillets are then further transported by truck to the ready-to-heat meal industry in Oslo (70 km).

## **Rice**

Parboiled white milled rice farmed in Italy was used in the meal. An LCA on Italian rice is the data source for this ingredient (Blengini et al., 2009). Energy consumption for cooking the rice is based on a processing plant in Ardoio, Belgium. The transports distance included are from farm to processing (boiling), Vercelli (Italy) to Ardoio (Belgium) 1040 km, and from processing to ready meal industry in Norway: Ardoio (Belgium) to Oslo (Norway) 1230 km.

## **Vegetables**

### ***Broccoli***

The broccoli in the meal is from Murcia, Spain. Previously assessed broccoli with the same origin is used as a data source of information for the farming stage (Angervall et al., 2006).

### ***Cauliflower***

The cauliflower florets are also from Murcia in Spain, data for this ingredient is from a British study on vegetable farming (Lillywhite et al., 2007).

### ***Carrots***

Carrots are of Norwegian origin, but due to lack of Norwegian data, data on Swedish carrots from an ongoing study at SIK regarding garden products (Davis et al., 2009) are used to approximate the carrots. 30 % of the carrots are assumed to be farmed in peat and 70% in mineral soil. Phosphorous and pesticide use are left out in this study due to lack of data.

## **Paprika sauce**

The paprika sauce approximated to be used in this study is a product at the market today; hence the ingredient composition can not be presented, due to confidentiality. Main ingredients are cream, milk, paprika, rape seed oil and leek.

### ***Cream***

The data for cream used in the paprika sauce is approximated with an average from two dairies. Cream produced in a dairy of whole milk powder production and cream produced during skim milk powder production. Both dairies are located in Sweden. Data on milk production at the farm level comes from a previously performed LCA study at SIK regarding milk production in Norrland, the north region of Sweden (Cederberg et al., 2007). The

agriculture practise for milk production in the Norrland region was assumed to be a good estimate of Norwegian production depending on agricultural practice.

### ***Milk***

Data on milk production at the dairy comes from a Swedish dairy (LRF 2002). At the farm level data comes from the same study as the above described cream (Cederberg et al., 2007).

### ***Paprika***

Paprika is left out of the study due to lack of data. Paprika is treated as a data gap in the calculations.

### ***Rape seed oil***

Data of rape seed oil has been assessed in previously performed projects at SIK. Data is from SIK's internal food database (SIK, 2009).

### ***Leek***

Data on onions has been used for approximating leek. Onion data is from SIK's internal food database (SIK 2009).

## **Packaging material**

Two types of plastic materials are used for packing the ready meal; one plastic container made of mono-extruded polypropylene that weighs 22.9 grams, and low density polyethylene (LDPE) packaging film on top of the plastic container (4.2 grams). The plastic container is manufactured by Færch in Holstebro, Denmark, and the packaging film is from Amcor in Ledbury, England. Data of packaging material and transportation comes from Ecoinvent's database (Ecoinvent, 2007).

## **Transports**

Transport distances have been inventoried as far as possible, but since the product chain is somewhat hypothetical in some steps, assumptions have also been made. For the incoming transports of ingredients and packaging material a 40 ton lorry with 50% used weight load has been used (Ecoinvent 2005). For the road transports of the ready meal a chilled lorry, EURO 3, including infrastructure with 50 % load has been used. Fuel production is from Ecoinvent 2007. Incoming transport to the ready meal industry includes transport of all ingredients and the packaging material. The distance between the ready meal industry and the wholesaler is assumed to be 20 km, the same distance is used from the wholesaler to retail, since all the facilities (i.e. ready meal industry, wholesale and retail) are assumed to be localized in the Oslo region.

## **Ready meal industry**

Energy consumption in the ready meal industry was based on a previously performed study on a ready-to-eat dish performed by SIK (Sonesson & Davis 2005). The type of electricity used is Norwegian electricity mix (Ecoinvent: Electricity, medium voltage, at grid/NO S) where electricity import is included.

## **Wholesale**

Data on storage at wholesaler was from a SIK-project where salmon was stored “less than a week”. This is approximated to consume 0.05 MJ of energy, which is used here as well (SIK, 2009).

## **Retail**

The Chicken meal was stored at the retailer for approximately six days. Energy consumption for refrigerators at the retailer is rather high due to open refrigerators. Data from a study performed by SIK is the foundation for energy consumption in retail stores; “short storage” is approximated to consume 0.2 MJ/kg chilled product (Carlsson & Sonesson 2000).

## **Household**

Assumed distance for transport from retail to household is 7.81 km, and 59 % of all customers go by car when grocery shopping, the rest go by bus or walk, based on Orremo et al. (1999). The car used is a passenger car based on Ecoinvent (2007). No climate burden has been ascribed to walking or going by bus.

Energy consumption in the household is modelled with Norwegian electricity mix (mainly hydro power) and electricity import based on an Ecoinvent process from 2007. Heating in microwave oven and chilling in fridge is driven by electricity. Microwaving the meal for 7 minutes in 800 W is calculated to consume 0.09 kWh. The microwave power value used in the calculations was based upon a simplified assumption where the energy efficiency of the microwave oven as well as the energy required for cooling of the magnetrons are not included. However, the corresponding influence on the resulting response values is negligible as compared to the order of magnitude of the total energy consumption of the LCA result. Electricity for refrigerant storage for three days is approximated with a function derived from a study performed by SIK (Sonesson et al. 2003). The average energy use for the refrigerators studied was 2.84 MJ/litre\*year. This function is accommodated by multiplying the volume occupied by the ready meal in the fridge (1150 ml) by three (to make up for the empty space in the fridge, which is thought to be 2/3 of the cabinet’s volume). This number is multiplied by 2.84 MJ (which is the average energy consumption of a refrigerator per litre and year, as previously mentioned) and later multiplied by the days stored in refrigerator (expressed as fraction of a year).

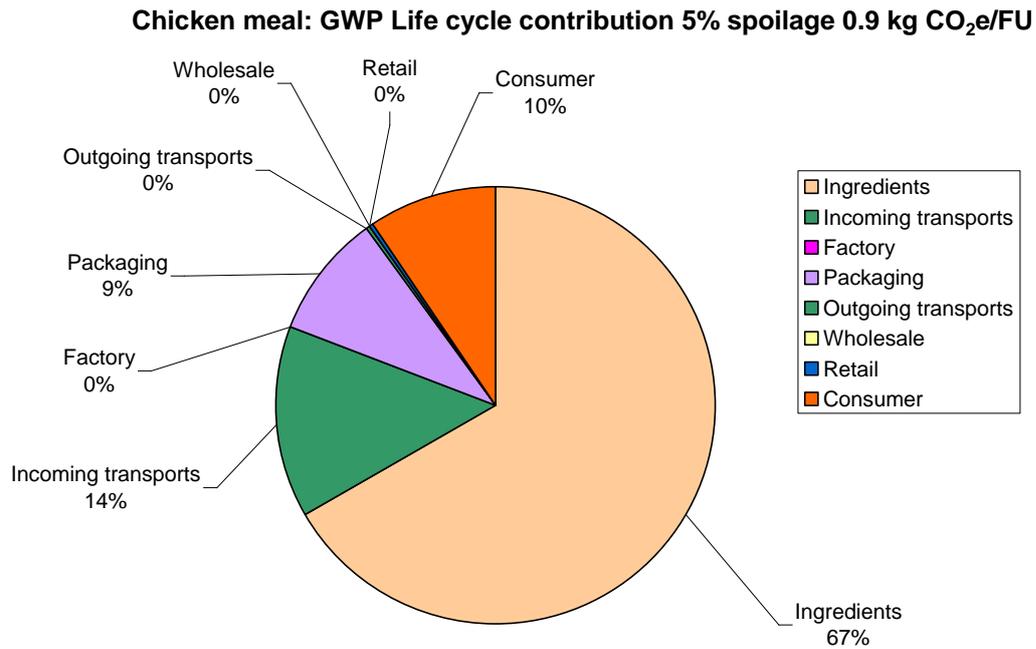
## Results Chicken meal

The environmental assessment results for the Chicken meal's in-depth LCA are presented below. A summary of the different impact categories results with 5 % respectively 20 % spoilage at the retailer is presented in Table 4. After the overall results a more detailed picture of the different impact categories' results are presented in pie charts, with the percental environmental burdens presented per life cycle phase. In the pie charts the percental spoilage at retail was 5 %. The environmental burden caused by the ingredient production is presented per ingredient in the bar charts following. By reducing the retail spoilage the environmental performance of the meal can be lowered by up to 12%, which is shown in the table below where both the eutrophication and acidification is lowered by 12%.

**Table 4. Summary of the overall results for the Chicken meal regarding the impact categories studied.**

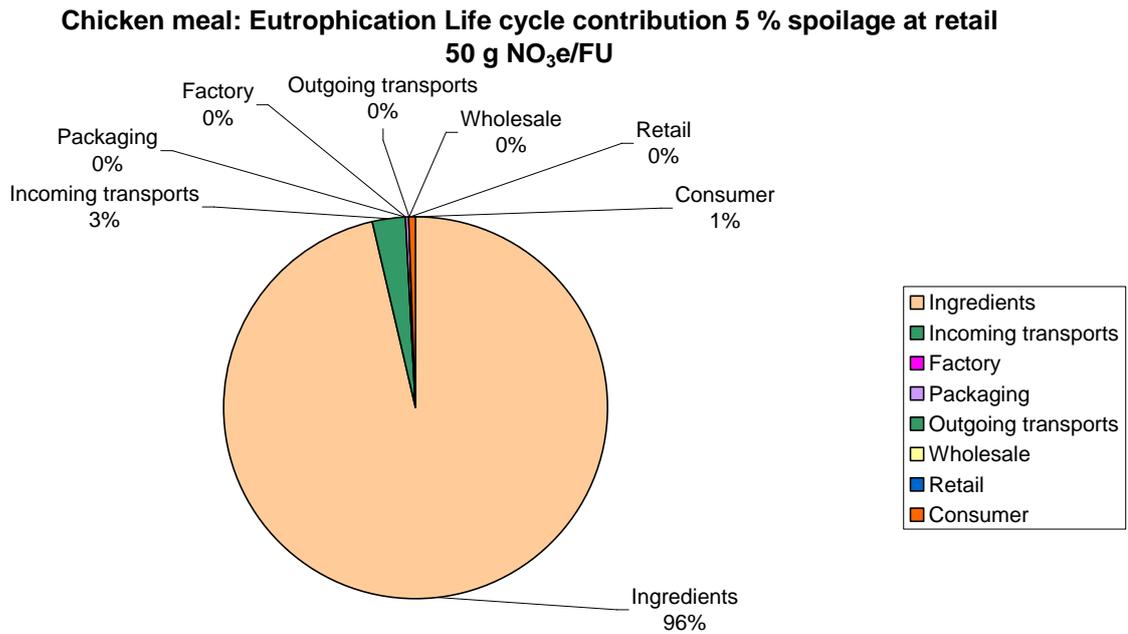
| Results for chicken meal per environmental impact category | 5 % spoilage at retail            | 20 % spoilage at retail           |
|--|-----------------------------------|-----------------------------------|
|  | <u>kg CO<sub>2</sub>e/product</u> | <u>kg CO<sub>2</sub>e/product</u> |
| <i>Greenhouse gas emissions</i>                            | <b>0.9</b>                        | <b>1.0</b>                        |
|  | <u>g NO<sub>3</sub>e/product</u>  | <u>g NO<sub>3</sub>e/product</u>  |
| <i>Eutrophication</i>                                      | <b>50</b>                         | <b>57</b>                         |
|  | <u>g SO<sub>2</sub>e/product</u>  | <u>g SO<sub>2</sub>e/product</u>  |
| <i>Acidification</i>                                       | <b>14</b>                         | <b>16</b>                         |
|  | <u>MJe/ product</u>               | <u>MJe/product</u>                |
| <i>Primary energy</i>                                      | <b>12</b>                         | <b>13</b>                         |

The following pie charts illustrate the different life cycle steps of the Chicken meal's contribution to the environmental impact. Figure 11 illustrates the global warming potential, figure 12 the contribution to eutrophication, figure 13 the category of acidification and figure 14 the consumption of primary energy.



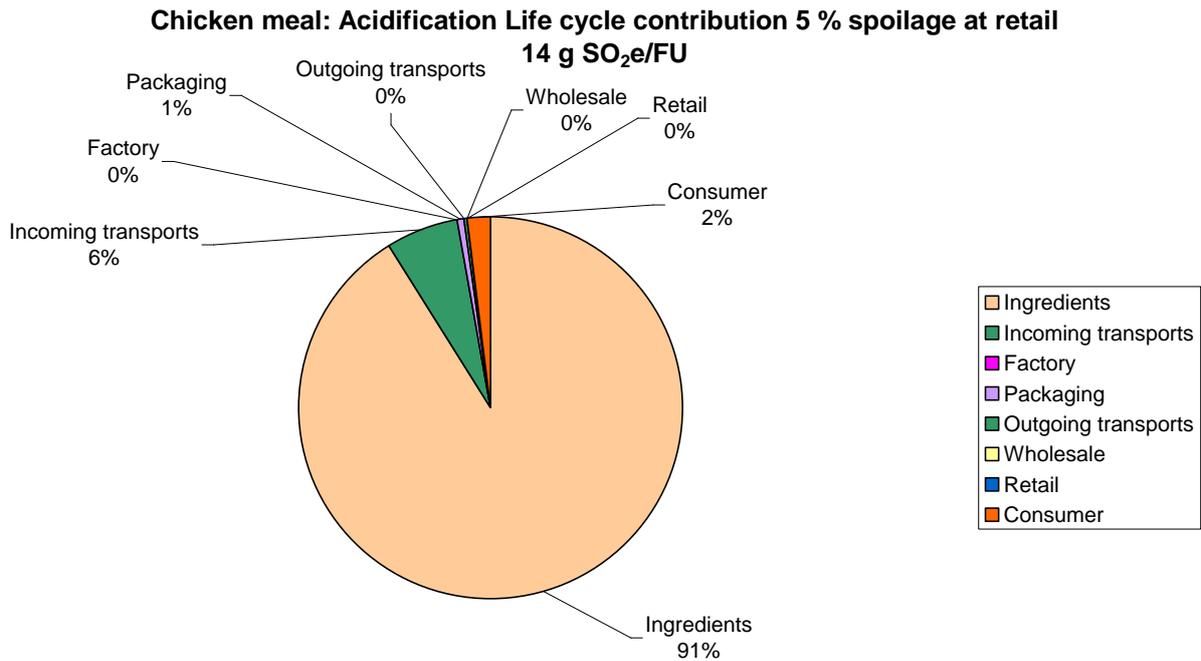
**Figure 11. Greenhouse gas emissions for the Chicken meal's lifecycle**

The ingredients in the Chicken meal are responsible for two thirds of the life cycle climate gas emissions. The incoming transports also play a crucial part by contributing 14 %. This large number could be explained by the long-distance transport for the rice and broccoli and cauliflower in the meal, all constituting large fractions of the meal. The packaging material, constituted by a 23 gram plastic container and a plastic film makes a significant impact as well. The consumer phase's relatively large part can be explained by the transport from the retailer to the household, where personal car transport was the assumed travelling mode for 59% of the consumers.



**Figure 12. Eutrophication potential for the Chicken meal's lifecycle**

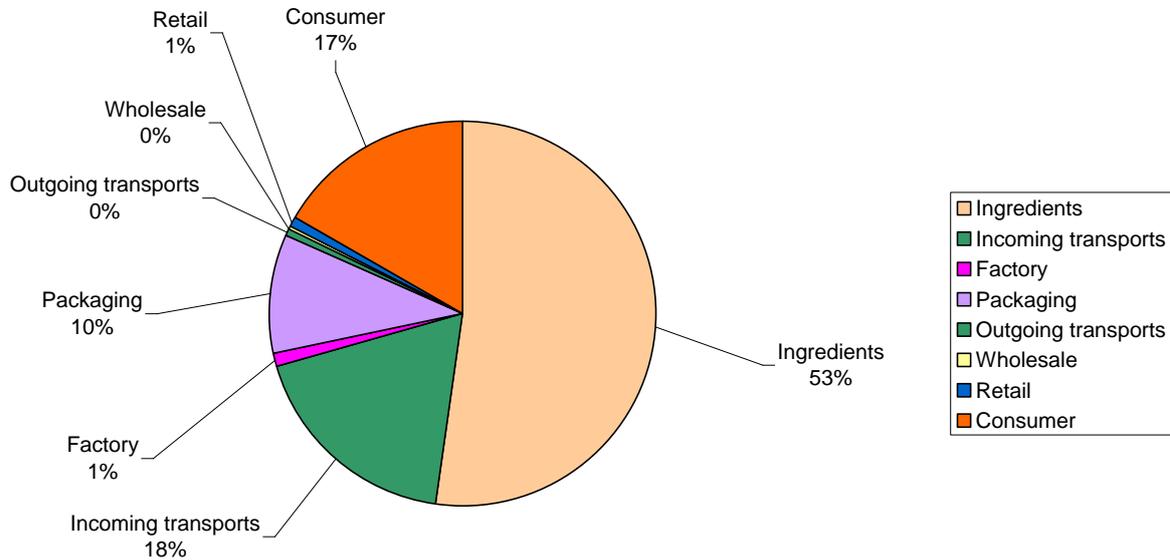
Almost all of the chicken meal's eutrophication comes from the agriculture activities, which is explained by the use of inorganic fertilisers and manure. The leakage of nitrogen and phosphorous from the fields end up in nearby and distant waters where they cause increased levels of nutrients which in turn intensify the algal bloom level, causing oxygen deficiency when algae are degraded.



**Figure 13. Acidification potential for the Chicken meal's lifecycle**

The ingredient phase is dominating the acidification potential of the meal, because the major part of the acidifying activities take place in the agriculture. Production of inorganic fertilisers cause emissions of N<sub>2</sub>O and when the fertiliser is spread it also causes emissions of N<sub>2</sub>O. This nitrogen oxide forms acids in the atmosphere which fall down with precipitation. The acidification attributed to transports is caused by combustion of fossil fuels (to a large extent from diesel). See Hunter's meal discussion, for more details regarding acidification.

**Chicken meal: Energy Life cycle contribution 5% spoilage at retail  
12 MJe/FU**

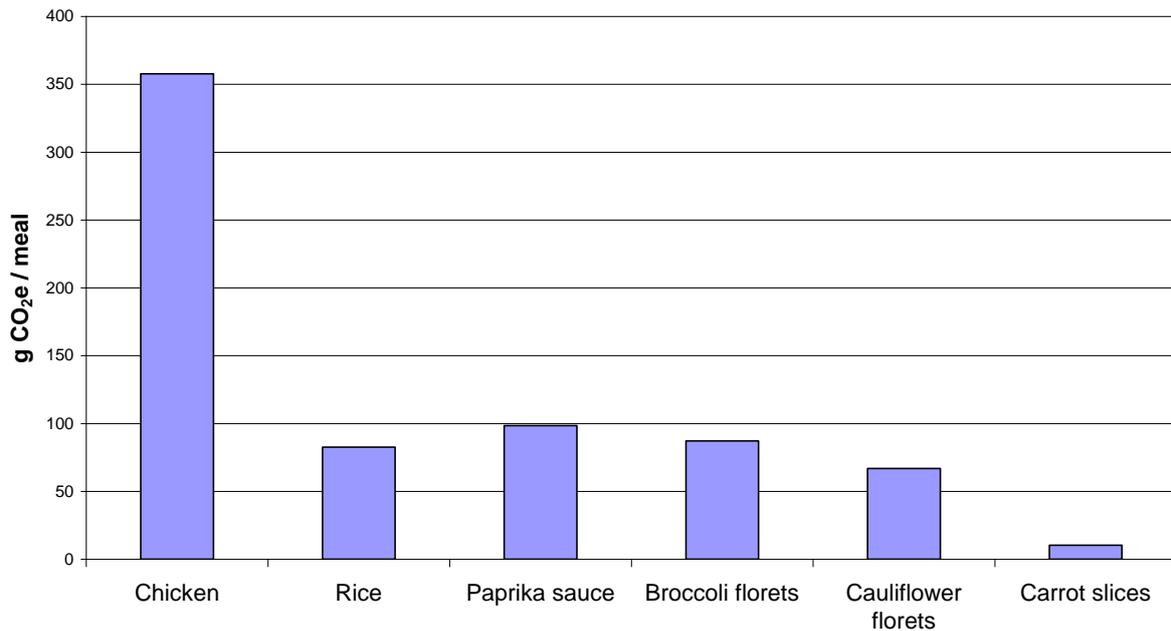


**Figure 14. Primary energy use for the Chicken meal's life cycle**

The primary energy use is somewhat coupled to the climate gas emissions, with the difference that the stages requiring only electric energy as for example the step of meal assembly, become more visible when assessing energy use (since this electricity does not cause climate gas emissions in the same extent as burning of fossil fuels).

For all the environmental categories considered was the production of ingredients the main contributor of the steps in the life cycle, see figure 11, 12, 13 and 14. Therefore, in this part of the result presentation we have chosen to concentrate on the ingredients. Figure 15, 16, 17 and 18 illustrates how much each of the ingredients contributes to respectively environmental impact. The ingredients are presented in weight order in each figure, the ingredient with largest proportion in the meal is presented to the left, and the amounts are descending to the right.

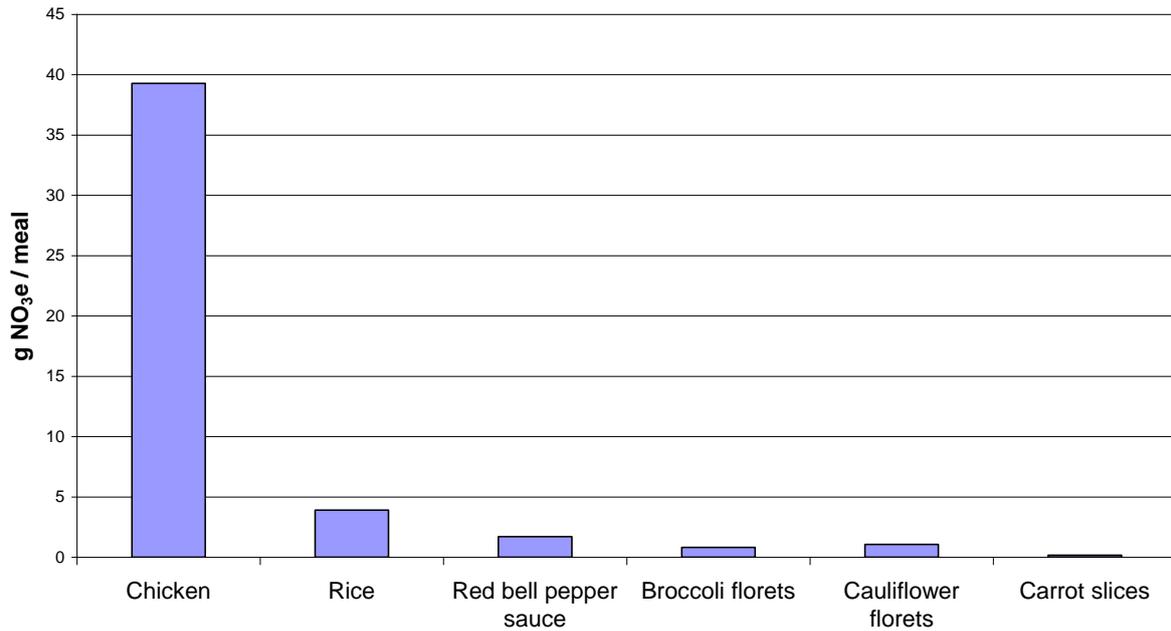
### Chicken meal ingredients contribution to GWP



**Figure 15. Greenhouse gas emissions for production of ingredients for the Chicken meal**

Chicken fillets contribute with the highest fraction, 51% of the ingredients' climate burden. Paprika sauce is the second largest contributor (14%); broccoli and rice contribute with approximately 12% each and cauliflower 10%. 1% is ascribed to the carrots, which is the ingredient that contributes the least to potential climate impact. The main part of the GWP assigned to the ingredients comes from the chicken production, since this is an animal ingredient requiring large amounts of feed. The relatively high figure for the paprika sauce is mainly caused by the cream and whole milk. These animal originated products cause extensive emissions of methane from the cows' feed digestion and dinitrogen monoxide from the feed production systems. Rice contributes to a relatively high climate gas emissions due to the methane emitted from the anaerobic processes in the farming fields. The Swedish carrot causes less climate gas emissions than the broccoli. It is both the farming and the transportation that gave this result. The Swedish carrot's farming phase causes less emission than the Spanish broccoli farming and the transportation of the broccoli from Spain to Norway gave a higher impact as well for the broccoli compared to the carrots.

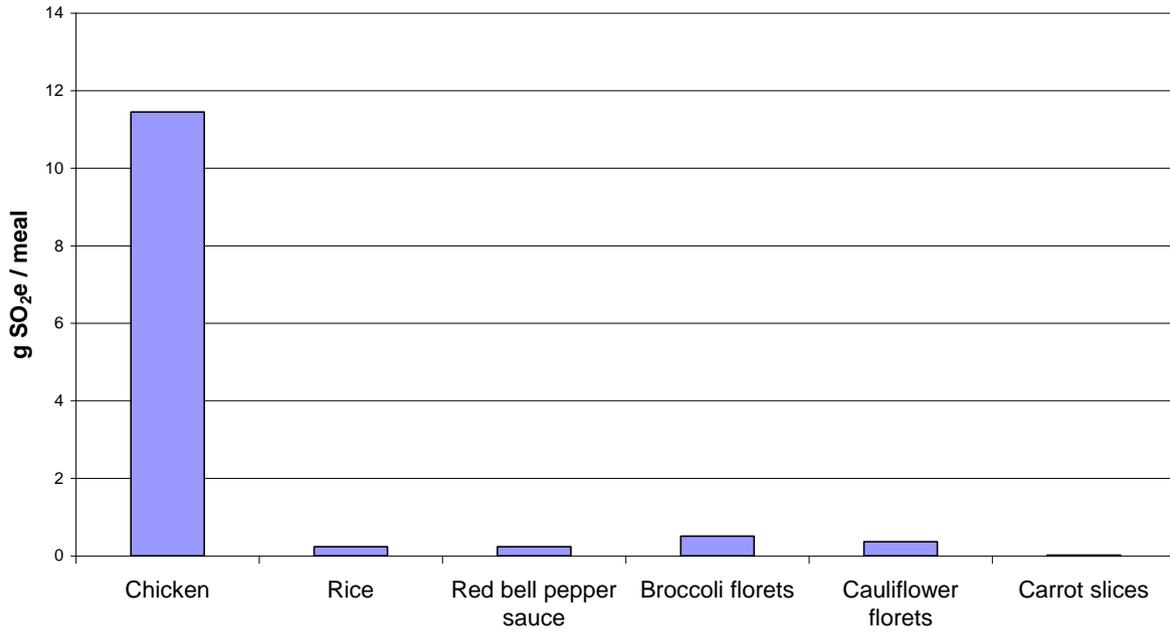
### Chicken meal ingredients contribution to eutrophication



**Figure 16. Eutrophication potential caused by the ingredients in the Chicken meal**

As previously mentioned the eutrophication is mainly caused by agricultural practise. Animal originated products has a higher impact compared to vegetables since the animals require large amounts of feed when reared. The farming of feed cause eutrophication through the fertilising compounds nitrogen and phosphorous that are spread on the fields and not thoroughly absorbed by the soil, but rinsed away to nearby waters by rainfall. Vegetable ingredients do not require as much farming activity as do animal products and hence these ingredients have less contribution to the eutrophication.

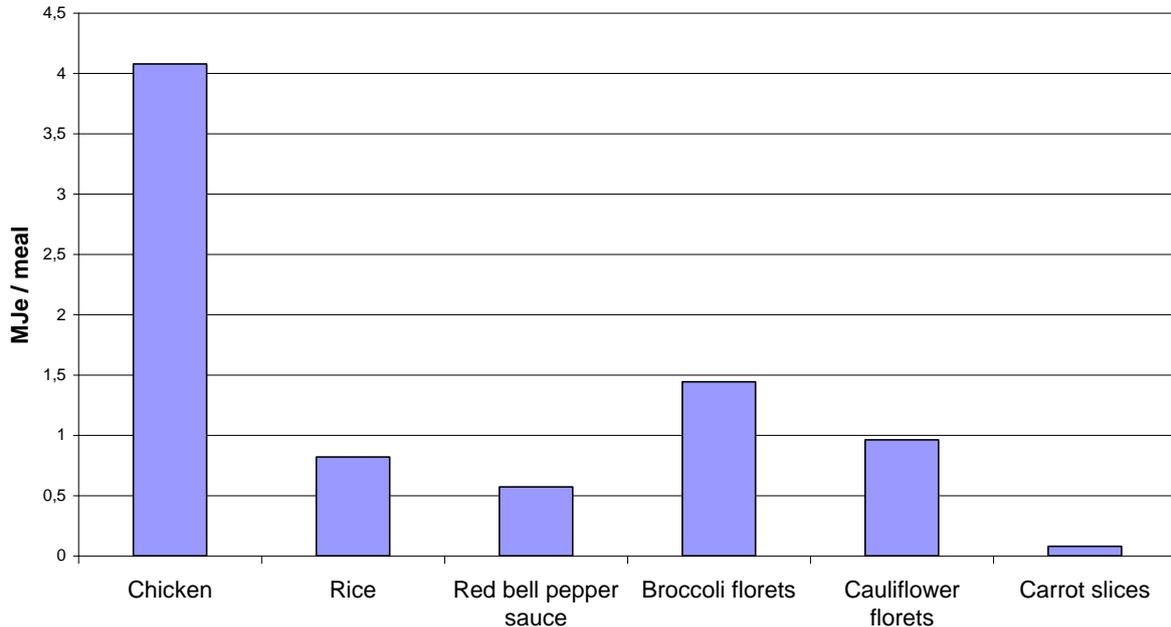
### Chicken meal ingredients contribution to acidification



**Figure 17. Acidification potential caused by the ingredients in the Chicken meal**

For the acidification the same relationship as for the eutrophication is true; animal products cause more acidification than do vegetable products. The sulphur oxides emitted are primarily caused by combustion of fossil fuels and the chicken production overshadows the other ingredients since there are many underlying chains for this ingredient.

### Chicken meal ingredients energy use



**Figure 18. Primary energy use for production of the ingredients in the Chicken meal**

The primary energy use is largest for the chicken fillet, because of the large inputs of energy required in this farming system. A rather high energy demand is ascribed to the broccoli florets as well, caused by both farming and transport of the vegetable. Energy use for carrot production is the lowest of these ingredients depending on a very efficient farming system in Sweden.

### Discussion Chicken meal

The ingredient production is the dominating lifecycle phase for the studied chicken meal. Most of the climate burden is attributed to the rearing of poultry. Meat products commonly cause a higher environmental impact than vegetable products, partially because of all the feed needed when rearing animals. For the ingredients in the paprika sauce the cream and whole milk were the main contributors to the environmental impact. Animal originated products are ascribed partial burden from the meat rearing system; i.e. not all the environmental burden is ascribed to the meat produced but also for instance milk-products (from the cow). The rice production system causes substantial emissions of methane from anaerobic microbiological processes that take place in the watery fields where the rice is grown.

The only impact category where the ingredient production is not totally dominating is the energy use. As appose to the climate impact category, the energy use shows numbers telling where the actual energy consumption takes place. The CO<sub>2</sub>-equivalents emissions are not always coupled to energy use (for instance when the emissions stem from biological processes), and that is the reason that the influence from ingredient production on energy consumption is lower than the influence the ingredient production has on the climate gas emissions.

Since the ingredients play a crucial role in the meal's environmental performance, the choice of ingredients is of great importance. Choosing another carbohydrate source than rice is also an alternative that may lower the climate gas emissions of the meal, potatoes for instance, are known to cause small green house gas emissions. For vegetables the transport distance is important for the category of global warming by choosing more near-farmed vegetables in the meal, the burden from long-distance transports would decrease. Regarding the packaging, the material used is of great importance when it comes to climate gas emissions and energy use. By choosing more cellulose products or biopolymers instead of fossil plastics as packaging material, emissions related to the packaging would be significantly lowered.

## 6. Screening assessment of six meals

There is no general methodology for an environmental screening assessment. The methodology chosen for the screening LCA in this study is based on the results and experience from the two in-depth LCAs (Hunter's meal and Chicken meal) together with the performers' 10 years of experience within the area of LCA in foods. The results from the two in-depth LCAs clearly show that it is the choice of ingredients that makes up most of the environmental impact independent of environmental impact category. It is also important to take the energy sources into account for the post-ingredients activities. The material used for the package and the amount of each packaging material may differ between the meals, which cause differences in environmental impact for the meals. Below, the working procedure used for the screening LCAs is presented. The working procedure used is based on the ISO-standard for LCA.

### Goal and Scope

The goal of the screening LCAs is to assess the global warming potential of six meals. The results will give an indication of which phase in the lifecycle contributes the most to the global warming potential, and also show which order of magnitude numerical results from a full carbon footprint analysis would have. To get a better quantitative result an in-depth LCA is required.

The system includes the production of the ingredients (ingredients that contribute with more than 5% to the total weight of the meal), the assembly manufacturing, the packaging, the retailer, the household as well as all transports involved. For production of the ingredients the included activities were the agricultural phase, the transportation of the raw material to the industry and the industrial refinement or treatment of the ingredients. One of the six meals (the lamb, rice and vegetable meal) does not pass the retailer since it is transported directly from the assembly manufacturer to the consumer.

The functional units used are:

1. One consumed meal of pasta, vegetables and tomato sauce at the household.
2. One consumed meal of lamb, rice and vegetables at the household
3. One consumed meal of mashed potatoes and kale with smoked sausage and bacon at the household.
4. One consumed meal of coated chicken fillets at the household.
5. One consumed meal of souvlaki i.e. chicken fillets with bell pepper at the household.
6. One consumed meal of pasta, cheese and vegetables at the household.

### Inventory of data

The information regarding the different dishes is retrieved from the other research groups within the Double Fresh project. The groups have either composed their meal or assessed it from other points of view than the environmental. Only ingredients that had a weight of at least 5% of the total meal were included in this screening LCA, except for cheese and egg which are considered to contribute a lot to the global warming potential. The environmental data for each ingredient was taken from literature data from LCA studies performed mainly by SIK but also from other sources. For all the data used a quality judgement has been performed and only data that fulfilled the goal of this screening study was used. The data sources for the assembly manufacturer, retailer and household are the same as the ones used

in the in-depth LCA of the Chicken meal. Data that is distinguished from the full LCA is the only data presented in this part. For more information please see the section of the Chicken meal. The ingredients and their respective weights in the meals are presented in Appendix 1.

### Assembly manufacturer

The energy used in the assembly factories are based on the industrial consumption of electric energy and the dominating energy source in the production countries, based on data from the International Energy Agency. The ready meals are produced in three European countries, see table 5.

**Table 5. Location of assembly manufacturer.**

| Meal  | Location of assembly |
|---|----------------------|
| Pasta, vegetables and tomato sauce              | The Netherlands      |
| Lamb, rice and vegetable                        | The Netherlands      |
| Mashed potatoes, kale, smoked sausage and bacon | The Netherlands      |
| Coated chicken fillets                          | Greece               |
| Souvlaki i.e. chicken fillets with bell pepper  | Greece               |
| Tortellini: Pasta, cheese and vegetables        | Liechtenstein        |

Data is gathered from IEA’s website regarding energy mixes in the Netherlands, Greece and Switzerland (representing Liechtenstein). Numbers representing the “Industry sector” have been used for distribution between electricity and the primary energy sources except for electricity. Data on the website is for 2006 (IEA, 2009). For the Netherlands an energy mix of 39 % electricity (Dutch production mix) and 61 % natural gas was used in the calculations and the electricity and gas data is from Ecoinvent (2007). The assumed Greek energy mix consisted of 39 % electricity (Greek production mix) and 61 % petroleum products. Data for the “petroleum products” used in the Greek energy mix was assumed being a mixture of ‘heavy fuel oil’ and ‘light fuel oil’ from the Ecoinvent database (Ecoinvent, 2007). Data for Liechtenstein was absent, and hence Swiss data has been used. The Swiss energy mix composition used was 49 % electricity (Swiss production mix), 26 % natural gas and 25 % petroleum products (same oil used here as in the Greek energy). The natural gas used in the processes is a European average from the Ecoinvent database (2007). The energy mixes are also presented in Table 6.

**Table 6. The energy mixes for the different countries.**

| Country                     | Energy mix  |
|-----------------------------|---|
| The Netherlands             | 39 % electricity, 61 % natural gas                          |
| Greece                      | 39 % electricity, 61 % petroleum products                   |
| Liechtenstein (Switzerland) | 49 % electricity, 26 % natural gas, 25 % petroleum products |

The amount of energy used is an average value of the energy used in the assembly manufacturing in the two in depth-LCAs.

### Retail, wholesale and household

The retail, wholesale and household were assumed to be situated in the same country as the assembly manufacturing. Data used for the wholesaler, retailer as well as the household activities are the same as in the two in depth LCAs with the exception that the energy mix

used is country specific. In the household a national electricity mix including imports is used for each meal (Data comes from Ecoinvent, 2007). Electricity used for heating the meals has been assumed to be the same as in the LCA of the Chicken meal. Hence 0.09 kWh is used for heating and 0.02 kWh is used for refrigeration (3 days). The waste figure at the retailer was assumed to be 5% as that is one of the goals of the technique development in the project Double Fresh. The waste figures today in the Netherlands of ready to eat and heat meals at the retail sector are approximately 20%.

## Packaging

The material type and amount used in the packaging are meal-specific, packaging data is presented in Table 7. The source of the environmental data for the packaging is Ecoinvent (2007). Except for the material an injection moulding is also included for the plastic packaging containers. The waste management of the packages was considered the same as in the in-depth LCAs. The transport distances for the packaging materials to the assembly factory was assumed to be the same as the distances for the plastic packaging material in the Norwegian ready meal dish, see section of LCA of the Chicken meal.

**Table 7. Material used for the packaging of the meals and the amount of each material.**

| <b>Meal</b>                                     | <b>Packaging material</b>   |
|---|-----------------------------|
| Pasta, vegetables and tomato sauce              | PP 27g, Cardboard 9g        |
| Lamb, rice and vegetable                        | PP 49g, Aluminium 3g        |
| Mashed potatoes, kale, smoked sausage and bacon | PP 27g, PA 2g, Cardboard 9g |
| Coated chicken fillets                          | PA 5g, LDPE 5g              |
| Souvlaki i.e. chicken fillets with bell pepper  | PA 5g, LDPE 5g              |
| Tortellini: Pasta, cheese and vegetables        | PET 28 g, LDPE 4g           |

## Transport of meals

The transport distance for the ingredients from processing to the assembly industry was assumed to be 300 km two ways. A 40 tonne truck was used with a 50% load based on Swiss transport data. For the transport between the assembling manufacturer and the wholesaler 100 km distance (two ways) was assumed, and the distance from wholesaler to retailer was also assumed 100 km (two ways). A 40 ton truck was used with a 50% load. For the consumer transport the same data as in the in-depth LCAs was used. Data for transportation was found in Ecoinvent (2007).

## Inventory data for ingredients and packaging

For more detailed information regarding recipes of the meals, see Appendix 1.

### Pasta meal

The ingredients included in the environmental assessment are pasta, zucchini and tomato sauce. The sauce content is restricted to tomato pulp and water, which together represents 86% of the sauce by mass. The pasta used in the calculations represents Italian pasta made from durum wheat, data is from an Italian study performed in 2001 (Notarnicola & Nicoletti, 2001). The weight gain of the pasta due to water absorption during cooking has been assumed 120%. The zucchini data used is for Swedish production and the source for information is SIK Food Database (2009). Unpublished data for tomatoes from an ongoing SIK-project in SIK

food database (SIK, 2009) has been used for the tomato sauce. Tap water from Ecoinvent (2007) has been used.

#### *Packaging material pasta meal*

The packaging consists of 26.8g polypropylene and 9.1g cardboard.

### **Culidish lamb meal**

As no climate emission data on lamb was available, data regarding sheep from an English study has been used for the meat portion in the meal (Williams et al., 2006).

The rice in the dish is the same rice as used in the full LCA of the chicken meal, and 1 kg of parboiled rice gives approximately 3 kg of cooked rice. Onions are from SIK Food database and represents Swedish production (SIK, 2009). The onions are the same as used in the paprika sauce in the chicken meal. Squash is from a confidential project performed by SIK and is extracted from SIK Food Database (SIK, 2009). The cream used in the Culidish lamb meal is the same cream as used in the Hunter's meal's mushroom sauce, based on milk from the Norrland region in Sweden.

#### *Packaging material culidish lamb meal*

Polypropylene and aluminium are the materials used for packaging, for one ready meal 49 g polypropylene and 3 g aluminium is required. The weight of the top lid is 1.1 g and is included in the total number for the polypropylene.

### **Sausage meal**

For the pork meat used in the sausage and bacon, data representing a Swedish average production in 2005 was used (Cederberg et al., 2009). The cream used in the sausage meal is the same cream as used in the Hunter's meal's mushroom sauce, based on milk from the Norrland region in Sweden. The kale in the sausage meal has been modelled with white cabbage, due to lack of data on kale. White cabbage (*Brassica oleracea*) belongs to the same species as kale, and was regarded as a good approximation. Data on white cabbage is from SIK food database (SIK, 2009).

Peeled potatoes are approximated to require 200 g potatoes for 100 g peeled potatoes; hence 50 % peel spoilage is used. Conventional potato farming in Sweden from SIK food database (SIK, 2009) was used.

#### *Packaging material sausage meal*

Three types of packaging materials were used in the sausage meal packaging: polypropylene, CPP-OPA (represented by nylon (PA)) and paper board (represented by cardboard). 27.2 grams of PP, 2.2 grams of PA, and 8.7 grams of paper board are used in the environmental calculation of the meal. Data was found in Ecoinvent's database (2007).

### **Chicken fillet meals (Coated chicken fillets and Souvlaki)**

Data on chicken production is a Swedish average value from 2005, based on a study performed by SIK (Cederberg et al., 2009). Since no data on pepper is present only the chicken fillet has been assessed for the souvlaki meal. For the coated chicken fillet meal only

the chicken has been assessed as well. 120 grams chicken was required for the souvlaki meal and 130 grams for the coated chicken fillet meal.

#### *Packaging material chicken fillet meals*

Both chicken meals are packed in the same type of packaging containing LDPE and PA. 10 grams of packaging is used per meal and 50% of each material is assumed, i.e. 5 grams LDPE and 5 grams PA.

### **Tortelloni meal**

For the tortelloni meal data for the pasta part of the tortelloni is from the same data source as the pasta in the pasta meal, representing Italian conventional farming (Notarnicola & Nicoletti, 2001). The same weight gain due to water absorption during cooking as in the pasta meal has been used (120%). Unpublished data for tomatoes from an ongoing SIK-project has been used for the fresh tomatoes and the tomato sauce (SIK, 2009). The tomato farming data represents Spanish production. Another ingredient in the pasta sauce is tomato purée, which is modelled with fresh tomatoes. Even though the weight limit for included ingredients in the calculations was set to 5 % the cheese is still included as it is a product with animal origin, which are known to cause large climate emissions. The cheese used to represent the ricotta and mozzarella is semi-hard cheese, data is from Berlin (2001 and 2002). Eggs, an ingredient in the tortelloni, is also included, although this ingredient represents only approximately 1% of the ingredients, due to the fact that this ingredient is of animal origin. Data used came from a SIK project regarding animal production (Cederberg et al., 2009) representing Swedish egg production in 2005.

#### *Packaging material tortelloni meal*

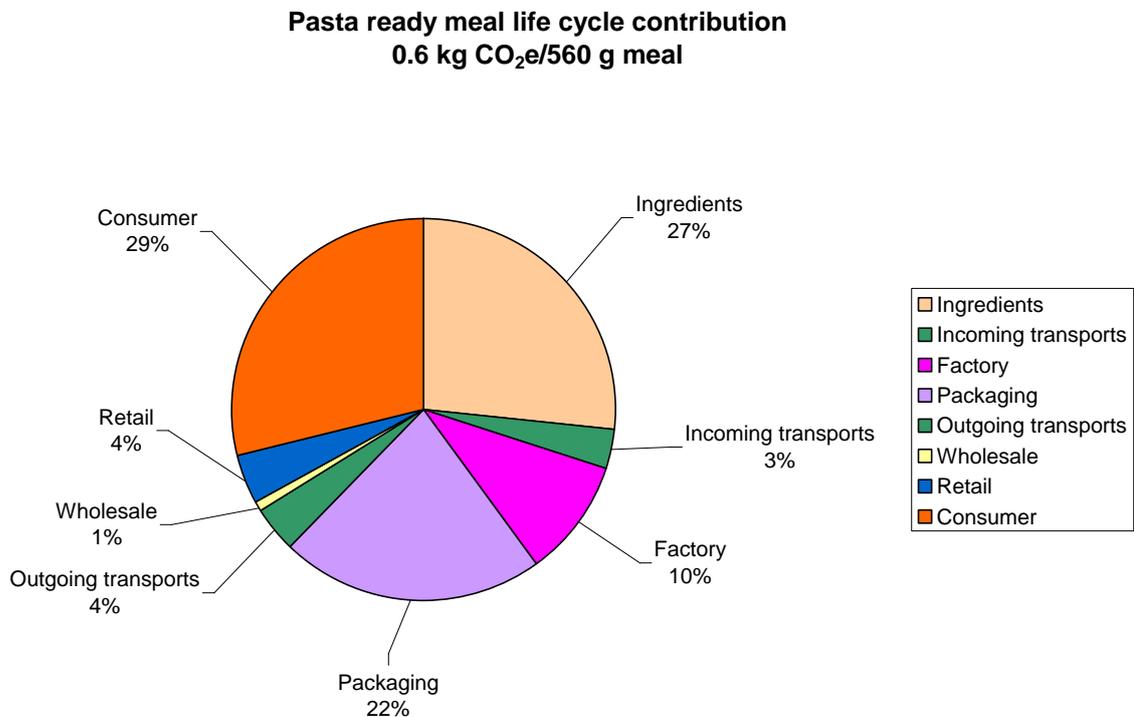
For the tortelloni ready meal 27.6 grams of C-PET is used. The lid film on top of the packaging is made of PET and PP and 4.2 grams material is needed for the 2.1 gram lid, due to loss in packaging machine. A secondary packaging of cardboard with the weight of 20 grams was also used.

## **Results**

The calculated screening assessment results in a life cycle perspective for the six meals are presented below (see figures 19, 20, 21, 22, 23 and 24). The charts illustrate the climate impact potential and the partial contribution from the different life cycle phases of the meals. The incoming transports are transports of ingredients and packaging material to the assembly plant. The factory compartment shows the energy used at the assembly plant. Packaging represents the production of packaging materials as well as the waste management of the packaging. The outgoing transports are transport from the assembly plant to the wholesaler, and wholesaler to retailer, while the transport from the retailer to the household is included in the consumer phase. The meal spoilage at retail (5%) is presented under the previously assessed steps: ingredients, incoming transports, factory, packaging, outgoing transports and wholesale; since the spoilage creates an increased demand for meals, which increases the climate burden of these previous activities. The quantitative results are also presented in a table to facilitate comparison between the meals, see Table 8. The meals' results are presented in the same order as they are presented in the charts below.

**Table 8. Climate gas emissions from the six studied ready meals.**

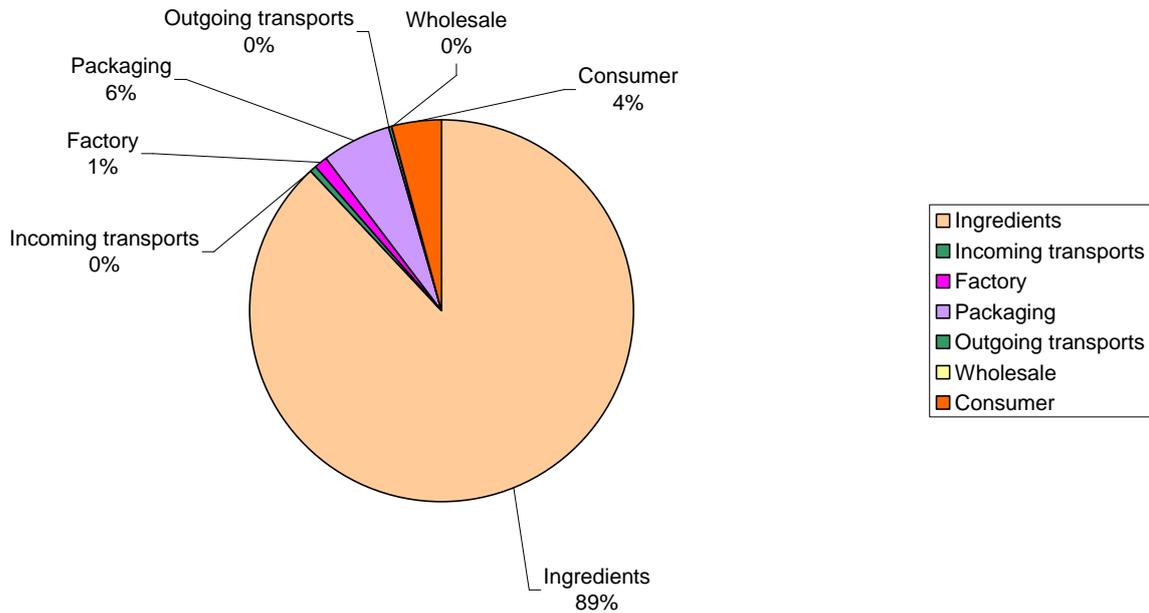
|                        | Meal 1 | Meal 2 | Meal 3 | Meal 4 | Meal 5 | Meal 6 |
|------------------------|--------|--------|--------|--------|--------|--------|
| CO <sub>2</sub> e/meal | 0.6    | 3.9    | 1.0    | 0.7    | 0.6    | 0.5    |



**Figure 19. Greenhouse gas emissions for the pasta meal's life cycle**

Since the pasta meal contains no ingredients with animal origin the ingredients part was not dominating as in the LCAs of Hunter's meal and Chicken meal. The consumer phase even overshadows the ingredient production, which is a rare case when it comes to a life cycle of a food. 417 grams of the total of 560 grams ingredients have been assessed in the calculations, the rest fall out due to the 5% rule (see goal and scope for the screening assessments) or lack of data. If more ingredients were included the climate burden of the meal would rise, but it is hard to say how much. Though, it is safe to say that the results would not grow to become as high as they would be if products or ingredients with animal origin would have been included in the meal. The large fraction for packaging could be explained by the polypropylene packaging fraction, since polypropylene is of fossil origin and causes emissions of greenhouse gases when incinerated. Another climate contribution from the packaging is the energy intense production. If using electricity from renewable resources like wind and solar in processing, the climate burden of packaging material may be decreased.

**Lamb ready meal life cycle contribution  
3.9 kg CO<sub>2</sub>e/490 g meal**



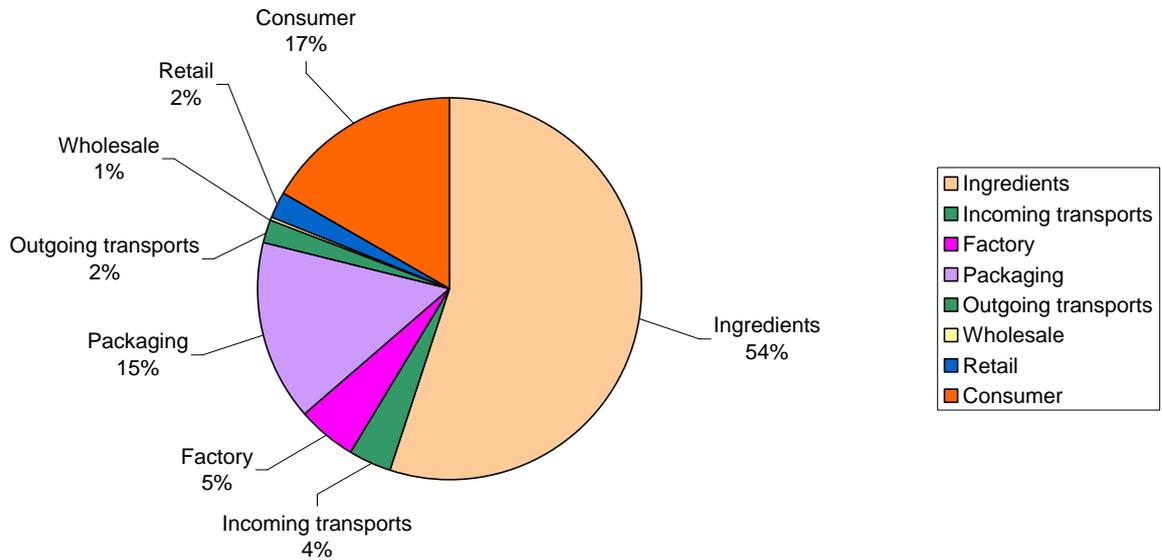
**Figure 20. Greenhouse gas emissions for the lamb meal’s life cycle**

The lamb meal result shows the other extreme of climate emissions from meal production, compared to the Pasta meal, with almost 90% of the climate burden ascribed to the ingredient production. This is due to the high climate burden from sheep production (which is the meat used to represent the lamb).

The reason for the high climate emissions from the sheep meat production is mainly the feed production where dinitrogen monoxide and carbon dioxide are emitted. The sheep’s feed digestion causes emissions of methane which is a potent climate gas. 353 out of 490 grams of the ingredients in the meal are assessed in the calculations.

As oppose to the vegetarian pasta meal here the consumer phase is not contributing in any large extent, only 4% of the life cycle’s emissions are attributed to the consumer phase. All other phases are overshadowed by the ingredient production phase.

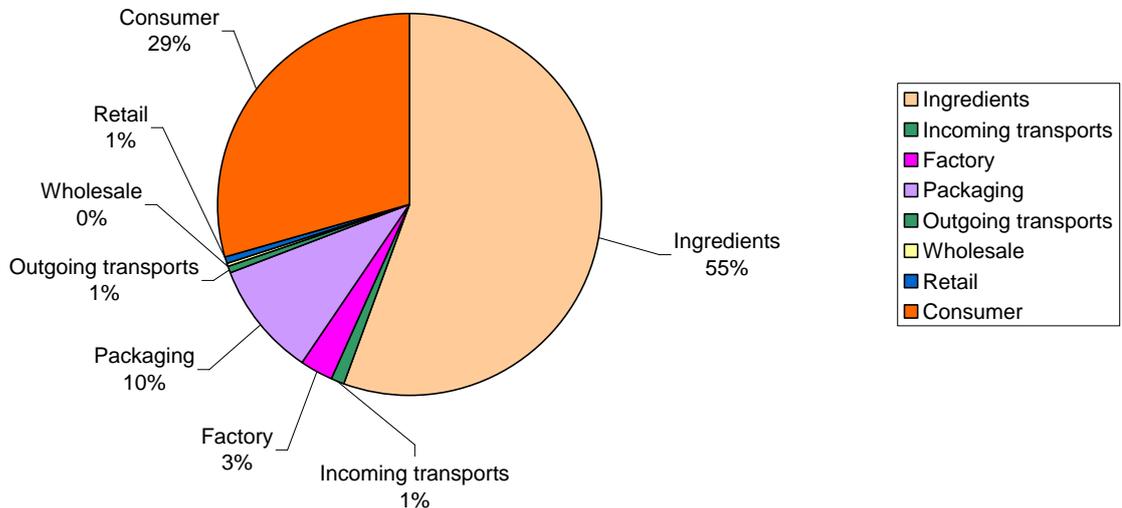
**Sausage ready meal life cycle contribution  
1.0 kg CO<sub>2</sub>e/500 g meal**



**Figure 21. Greenhouse gas emissions for the sausage meal’s life cycle**

For the sausage meal the ingredient production is responsible for more than half of the life cycle climate emissions for the meal. The consumer phase and the packaging are on the same level when it comes to climate impact, and for the consumer phase it is the transport from retail to household that makes the largest impact.

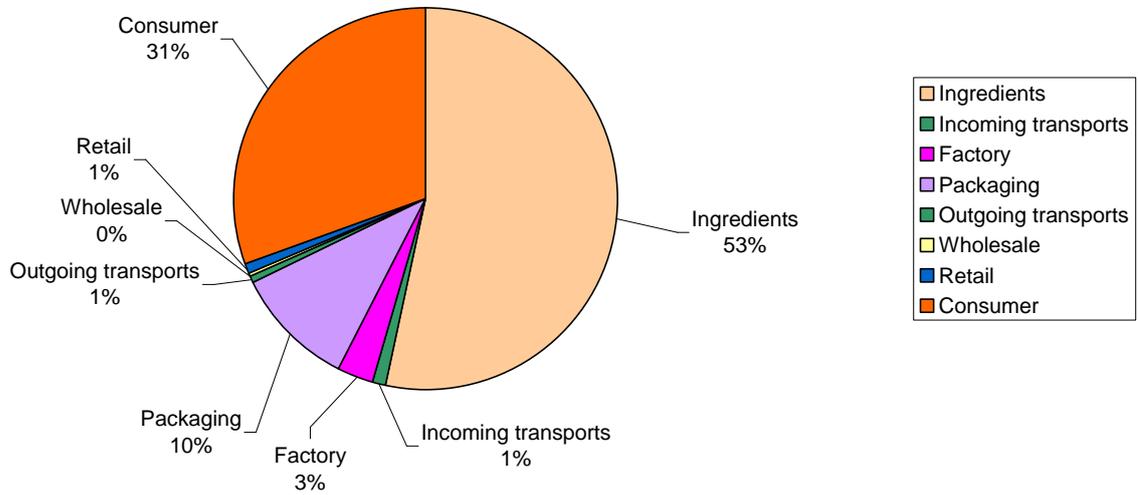
**Coated chicken ready meal life cycle contribution  
0.7 kg CO<sub>2</sub>e/130 g meal**



**Figure 22. Greenhouse gas emissions for the coated chicken meal’s life cycle**

The coated chicken meal is not actually a whole meal, but a one-ingredient “meal”. Hence, 130 grams of chicken fillet is assessed in the calculations. The climate burden of chicken is relatively low in comparison with other types of meat; for instance lamb, as in the meal presented above. The reason that the pasta meal still is in the same order of magnitude as the chicken is that the weight of the ingredients assessed in the pasta meal is almost three times that of the coated chicken fillet. The small amount of packaging material used (10g/meal) gives the packaging phase a low climate burden in comparison with the other meals.

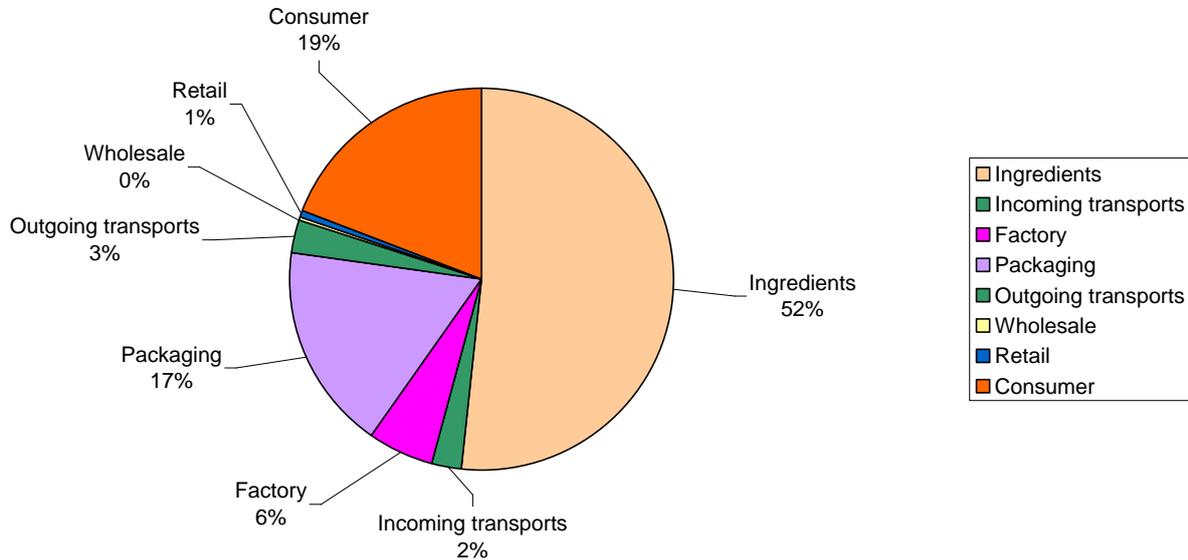
**Souvlaki chicken ready meal life cycle contribution**  
**0.6 kg CO<sub>2</sub>e/140 g meal**



**Figure 23. Greenhouse gas emissions for the souvlaki meal's life cycle**

Since the chicken meals do only differentiate from one another in terms of weight, where the souvlaki meal contains 120 g chicken and the coated chicken meal consists of 130 gram chicken, these meals are almost identical in climate burden, with a higher burden for the heavier meal.

**Tortelloni ready meal life cycle contribution  
0.5 kg CO<sub>2</sub>e/380 g meal**



**Figure 24. Greenhouse gas emissions for the tortelloni meal’s life cycle**

The result for the tortelloni meal is somewhat higher than the pasta meal, if the weight is taken into account when looking at the climate gas emissions. Here the ingredients play a more crucial part, contributing to about half of the life cycle emissions. No meat is included in the meal, but both eggs and cheese are products of animal origin, which gives them a higher climate load than vegetables (since the climate burden of animal farming is shared among the meat and other eatable products from the animal). The large impact of the packaging is due to the PET plastic and LDPE used, which have been included in the assessment.

## Discussion

It is obvious that the ingredients play a crucial part in determining the meal’s climate gas emissions, the more animal products included, the higher the climate load. The reasons that animal derived products cause larger climate gas emissions are the feed production needed to sustain the animals and the animal digestion. For more information about the animal rearing, see discussion section in the Hunter’s meal life cycle assessment.

Since this is only a screening LCA with no specifically inventoried productions, only reasoning regarding ingredient production and other phases in the life cycle is possible. As the same transport distances have been used for all ingredients no comments can be made about that. Other phases that could make contributions to the climate were the consumer and packaging phase. For reduction of the emissions caused by the household it is important to not go grocery shopping by car, since most of the consumer-related emissions are ascribed to the home transport. Even though other errands run at the same time are taken into account when determining the transport distance. The packaging is the other dominating phase, besides ingredient production and household. Here it is an advantage to use as small amount of fossil plastic material as possible, as the fossil nature of the material contribute to a higher level of

greenhouse gasses in the atmosphere when the material is incinerated. To use a renewable energy resource in packaging production may also reduce the climate gas emissions from packaging production, since it is a very energy intense process.

The transports used in this study do not correctly reflect the real transport situation since only a one-way distance has been assessed here. If the analysis was to be updated, two-way transport distances should be used as that is a more accurate picture when looking at transports in general (trucks are seldom loaded when they have discharged their cargo). The transport contribution would hence probably be higher if assessed with accurate loads. Data for wholesale and retail is the same as for the two full LCAs, and make a small contribution to the life cycle emissions. Here the energy source is the most important contributor. The energy sources are most often electricity, which makes the low impact reasonable. The ready meal assembly plant has a small contribution when looking at the life cycle contribution as a whole. The energy mixes from the countries where the ready meal assembly factories were situated were used. A suggestion would be to use green labelled electricity mix from renewable energy sources.

## 7. Overall discussion

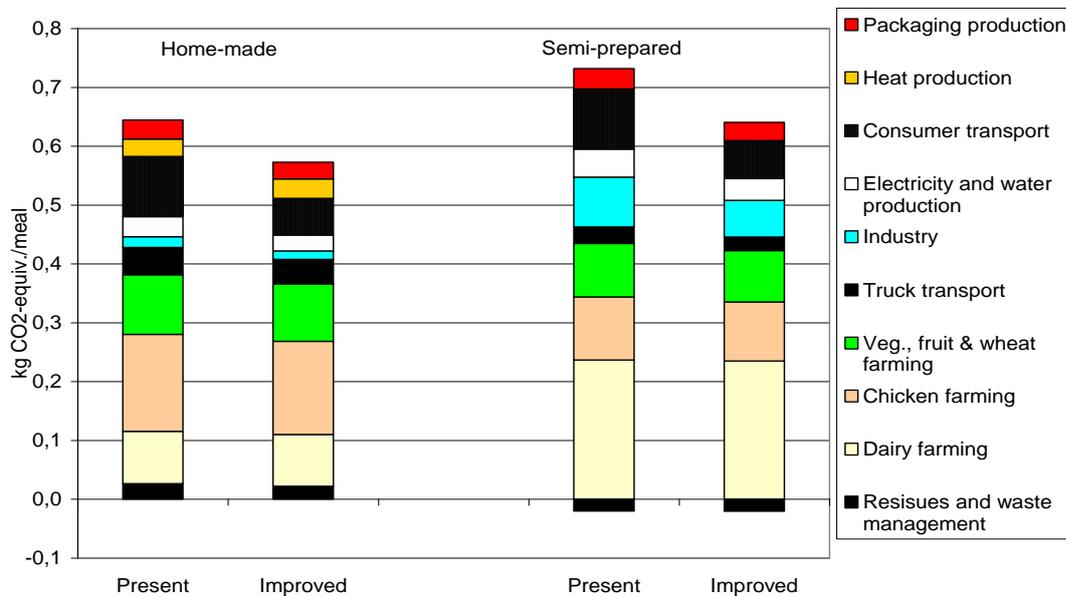
Environmental life cycle assessment can be considered as a new subject within academia. Between 1969 and 1972 the method of LCA began to be used. The area of assessment was packaging and waste management. After that the method was more commonly used for energy assessments during the oil crises (emerged in 1972) (Baumann and Tillman, 2004). In 1990s LCA entered the area of food products. Examples of early works are Weidema et al's (1995) Life Cycle Screening of Food Products and Karin Andersson's PhD thesis of Life Cycle Assessments (LCA) of Food Products and Production Systems in 1998. Karin Andersson fulfilled her PhD work at SIK. The work of LCA within the food sector at SIK has been going on since then and today with 16 years of experience SIK has fulfilled many LCA studies of foods, both studies in the area of research but also many studies performed as consultancy work for food companies. This experience of LCA in foods and the access to many data sets of our earlier studies made it possible for us to perform this project of LCAs of ready meals within the EU project Double Fresh. Within literature there are few LCA studies of ready meals. The reason is probably the high number of data sets required for all the ingredients both at the farm level and production level.

The quality of data and data sets varies for the different ingredients in the studies. To be able to keep as high quality of data as possible we have used data sets from reliable sources and data sets with documented data history. We also used data as new as possible as the goal was to make an assessment of the environmental impact of today. Nevertheless, it would have been an improvement for the data quality if it would have been possible to make personal visits at each ingredients company and make the data inventory at site. This has not been done in this study and is in fact rare for LCA studies in general. The common custom is to make personal visits to the actor or actors regarded to have an important role (either for decision making or environmental contributor) of the chain. The other data and data sets required for the assessment originates often from literature or data bases. For the LCAs included in this study we made personal visits at some ingredients companies for the chicken study but for the Hunter's meal and the screening assessments, data from literature and data bases were used.

Although, there are few studies performed of LCAs of ready meals, fortunately two studies were found which could be used to verify our results. For the Hunter's meal we found a meal study of meatballs and potatoes performed by Sonesson et al. (2005). They made environmental assessments of three types of meatball meals; home cooked, semi-prepared and ready meal. It was the ready meal which was most similar to our Hunter's meal. The meatball ready meal got a global warming potential result of 1,6 kg CO<sub>2</sub>-eq/meal. The Hunter's meal got 0,9 kg CO<sub>2</sub>-eq/meal. The two meals do not consists of exactly the same ingredients and not the same amount of each which is the reason for the difference. The higher number of the meatball dish depends to a high extent of the content of beef meat within the meat ball dish. There is no beef meat at all in the Hunter's meal. Beef contribute to a very high extent to the global warming potential with 20 CO<sub>2</sub>-eq per kg carcass weight (from farm to retailer) compared to pork that contribute with 3,5 CO<sub>2</sub>-eq per kg carcass weight (from farm to retailer) (Cederberg et al. 2009). To conclude, the results of the two dishes are within the same area of magnitude which gives us a verification of the correctness of the result of Hunter's meal.

To be able to verify our Chicken meal we used a study of Davis and Sonesson (2008). They performed a study of two chicken meals; one home made and one semi-prepared in industry before it was finalised at home. They also made scenarios of improvements for the two meals.

The result of the global warming potential of the meals is illustrated in figure 25. It is the Semi-prepared chicken meal at present in figure 25 which is the meal most similar to our Chicken meal with a result of ca. 0,7 kg CO<sub>2</sub>-eq/meal. The result of our Chicken meal was 0,9 kg CO<sub>2</sub>-eq/meal. The two meals do not consist of exactly the same ingredients and not the same amount of each which is the reason for the difference. For example our chicken meal included a higher weight of chicken. Nevertheless, the quantitative results of the two meals are in the same area which gives us a verification of the correctness of our result.



**Figure 25. The contribution to global warming from two chicken meals; home-made and semi-prepared. A study made of Davis and Sonesson (2008).**

The result of the screening assessments fulfilled in this study cannot be compared to the results of the in depth life cycle assessments of the Hunter's meal and the Chicken meal. A screening assessment is very much a screening both in the methodology used and how the result can be used. The methodology is described in the section about the screening assessment. The goal of the result in a screening assessment is not to find exact figures or percentage, it is to find out what makes a large contribution to in this case the global warming potential and what is less important for the meal under study. An overall conclusion is that the meals containing animal originated products get a higher contribution to the global warming potential than vegetarian dishes.

The overall aim of the in-depth assessments was to quantify the environmental improvement potential possible by decreasing the wastage of ready meals at the retailers from 20% to 5%. When the waste figures was decreased from 20% to 5% at the retailers the environmental impact improved the most was the category of primary energy by 14% for the Hunter's meal and for the Chicken meal it was eutrophication and acidification with a 12% improvement. This means that a decrease of wastage of products makes significant improvements of the environmental impact from ready to eat meals as well as freshly cooked meals.

## 8. Conclusions

The overall aim of the in-depth assessments was to quantify the environmental improvement potential possible by decreasing the wastage of ready meals at the retailers from 20% to 5%. The specific objectives related to the overall aim were to assess the environmental impact of one ready-to-eat meal and one freshly cooked meal. On top of that six meals were assessed by a screening LCA methodology. The most important findings from this work are listed below.

- The environmental impact decrease when the wastage of products is decreased from 20% to 5%. For the environmental category of primary energy the Hunter's meal improved by 13% and for the category of acidification and eutrophication the improvement was 12% for the Chicken meal.
- The quantitative result from the assessment of the Hunter's meal were with a spoilage of 5% at the retailer: global warming potential 0,9 kg CO<sub>2</sub> eq., eutrophication 39 kg NO<sub>3</sub> eq., acidification 7 kg SO<sub>2</sub> eq. and primary energy 13 MJ.
- The quantitative result from the assessment of the Chicken meal were: global warming potential 0,9 kg CO<sub>2</sub> eq., eutrophication 50 kg NO<sub>3</sub> eq., acidification 14 kg SO<sub>2</sub> eq. and primary energy 12 MJ.
- For both the Hunter's meal and the Chicken meal it was the production of ingredients including agriculture that was the step in the life cycle that gave the largest contribution to the environmental impact.
- Also the screening LCAs showed that the ingredients production was the step that contributed most to the global warming potential for five of the six meals.
- Among the ingredients it is the animal originated products that contributed most to the environmental impact.

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**Appendix 1. The ingredients and their respective weights for the six meals. The ingredients in italics are not included in the assessment as their weight is less than 5% of the total meal. Ingredients with animal origin are sometimes included despite small weight percentage. The ingredients in red are not included due to data deficiency.**

| <b>Pasta, vegetables and tomato sauce, 560 g</b> | <b>Lamb, rice and vegetables, 490g</b> | <b>Mashed potatoes and kale with smoked sausage and baked bacon, 500 g</b> | <b>Coated chicken fillets, 130 g</b> | <b>Souvlaki, i.e. chicken fillets with bell pepper, 140 g</b> | <b>Tortelloni, i.e. Pasta, cheese and vegetables, 380 g</b> |
|--|--|--|--------------------------------------|---|---|
| Pasta, 225g                                      | Lamb fillet, 125g                      | Smoked sausage, 75g:   | Chicken meat, 130 g                  | Chicken meat, 100±20 g  | Tortelloni with spinach-ricotta filling, 180g:              |
| Vegetables, 200g:                                | Rice, 150g                             | Pork, 55g  |                                      | Blanched Bell pepper, 15±5 g                                  | Wheat flour, 72g  |
| Egg plant, 50g                                   | <i>Pasteurized pesto, 15g</i>          | Pork rind, 6.9g  |                                      |   | Water, 64.8g  |
| Zucchini, 50g                                    | <i>Olive oil, 20g</i>                  | Bacon, 4.8g  |                                      |   | <i>Spinach, chopped, frozen, 10.8g</i>                      |
| Pre-cooked mushroom, 50g                         | Vegetable mix 150g:                    | <i>Pork protein, salt, stabilizers E450, E452...etc., 7.8g</i>             |                                      |   | Ricotta cheese, 7.2   |
| Red bell pepper, 50g                             | Egg plant, 28g                         | Bacon, 31.6g:  |                                      |   | Mozzarella pasta cheese, ground, 7.2g                       |
| Tomato sauce, 165g:                              | Zucchini, 28g                          | Pork, 27.6g  |                                      |   | <i>Breadcrumbs, 7.2g</i>                                    |
| Tomato pulp, 71g                                 | Mushrooms, 28g                         | Salt, 1.1g   |                                      |   | Whole egg, 5.4  |
| Water, 71g                                       | Bell pepper, 28g                       | <i>Dextrose, smoke, preservatives E250, E252...etc., 2.85g</i>             |                                      |   | <i>Salt, iodised, 1.8</i>                                   |
| Tomato purée, 7g                                 | Onion, 38g                             | Potatoes, 174g   |                                      |   | <i>Dry spice mixture (without MSG)</i>                      |
| Onion, 3.5g                                      | Red wine sauce, 30g:                   | Vegetables and spices, 219g:   |                                      |   | <i>Rapeseed oil, refined</i>                                |
| Sun-dried tomatoes, 3.5g                         | Red wine, 15g                          | Kale, 142.1g   |                                      |   | <i>Tapioka starch</i>                                       |
| Black olives, 3g                                 | Sour cream, 11.5g                      | Onion, 15.8g   |                                      |   | <i>Parmesan cheese aroma</i>                                |
| Sugar, 2g  | Rosemary, 2g                           | Cream, 31.6  |                                      |   | <i>Garlic powder</i>  |

|                            |                          |  |  |  |  |
|----------------------------|--------------------------|--|--|--|--|
| <i>Modified starch, 1g</i> | <i>Garlic, 1g</i>        | <i>Phase (sunflower oil, turnip oil hardened, saltetc.), 19g</i> |  |  | <i>Onions</i>  |
| <i>Salt, 1g</i>            | <i>Salt</i>              | <i>Salt, 1.3g</i>  |  |  | <i>Nutmeg, ground</i>                                |
| <i>Olive oil, 1g</i>       | <i>Pepper</i>            | <i>Nutmeg, 0.2g</i>  |  |  | <i>Ground pepper, black</i>                          |
| <i>Basilica</i>            | <i>Purity 68 (E1414)</i> | <i>Corn starch, 4.1g</i>   |  |  | <i>Tomato sauce with basil, 100g:</i>                |
| <i>Oregano</i>             |                          | <i>White pepper, 0.2g</i>  |  |  | <i>Tomato, peeled, cut in cubes, aseptic, 47g</i>    |
| <i>Pepper</i>              |                          | <i>Chicken glace (chicken, yeast extract, sugar etc.), 5.7g</i>  |  |  | <i>Water, 25g</i>                                    |
|                            |                          |  |  |  | <i>Onions, fine cut, blanched, frozen, 13g</i>       |
|                            |                          |  |  |  | <i>Tomato puree 36/38%, 9g</i>                       |
|                            |                          |  |  |  | <i>Rapeseed oil, refined, 1g</i>                     |
|                            |                          |  |  |  | <i>Corn starch, 1g</i>                               |
|                            |                          |  |  |  | <i>Salt, jodised, 1g</i>                             |
|                            |                          |  |  |  | <i>Vegetable bouillon</i>                            |
|                            |                          |  |  |  | <i>Sugar</i>   |
|                            |                          |  |  |  | <i>Garlic powder</i>                                 |
|                            |                          |  |  |  | <i>Parsley, cut, dried</i>                           |
|                            |                          |  |  |  | <i>Basil, rubbed, dried</i>                          |
|                            |                          |  |  |  | <i>Ground pepper, white</i>                          |
|                            |                          |  |  |  | <i>Fresh tomato, 75g</i>                             |
|                            |                          |  |  |  | <i>Fresh spinach leaves, 4g</i>                      |
|                            |                          |  |  |  | <i>Mozzarella pearls, 10g</i>                        |
|                            |                          |  |  |  | <i>Chips of hard cheese, 6g</i>                      |
|                            |                          |  |  |  | <i>Pine nuts, 2g</i>                                 |
|                            |                          |  |  |  | <i>Coating(1% agar+1% maltodextrin solution), 3g</i> |

