LCA of Packed Food Products

- the function of flexible packaging -

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Executive Summary

"LCA of Packed Food Products: the function of flexible packaging"

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The evaluation of the environmental performance of packaging usually concentrates on a comparison of packaging materials. Other aspects including sustainable consumption and production of packed goods are often neglected. The same applies to the functional role of flexible packaging, which is the distribution of goods to society to satisfy human needs.

Broader approaches, which focus on the life cycle of packed goods, including the entire supply system and the consumption of goods, are necessary to get an environmental footprint of the food supply system with respect to sustainable production and consumption.

And as the only reason to produce packaging is to enable the consumer to consume products the relevant question from a sustainability point of view can be only to optimize the sustainability along the total supply chain of consumer goods rather than focussing on parts of it.

The three main targets of this study are:

- the investigation of the environmental performance of flexible packaging with respect to its function within the life cycle of goods, i.e. within the supply chain and consumption of goods,
- the investigation of the role of flexible packaging in view of resource efficiency and prevention of spoilage of packed goods, and
- the investigation of the environmental relevance of stages and interdependencies within the life cycle of goods while taking consumers' patterns and portion sizes into consideration.

The study illustrates the environmental relevance of flexible packaging within the supply chain. While the results of this study are not immediately transferable to other packaging systems or types of products this study shows that the environmental impact from the packaging of the investigated sample products is minor in comparison to the impact from the production of the product, its processing and the consumer behaviour in the use of the product. Additionally, depending on the product, packaging can contribute to minimise the environmental impact of production, processing and use by reducing spoilage and over-consumption.

Three case studies were chosen to represent different types of flexible packaging as well as a range of products. These case studies are:

- Ground and instant coffee in pouches and stick-packs made of plastic laminate with an aluminium foil layer as a barrier
- Frozen spinach leaves in a mono-plastic bag
- A family and single portion pack of butter wrapped in a laminate with an aluminium foil layer

The results of this study are calculated for eight environmental indicators based on the CML 2001 method. The main impact assessment and discussion is based on five indicators which are:

- Cumulative energy demand (CED), non-renewable (MJ eq.)
- Global warming (kg CO_2 eq.)
- Ozone layer depletion (ODP) (kg CFC-11 eq.)

- Acidification (kg SO_2 eq.)
- Eutrophication (kg PO_4^{3-} eq.)

Case Study: Coffee

The life cycle inventory for coffee encompasses the whole food supply system from the cultivation, processing, packaging, and transportation of the coffee beans to production and packaging of ground and soluble coffee, transport to retailers and households, and the brewing ending with a cup of coffee ready to drink. The growing as well as the first stages of coffee processing occurs commonly in countries near the equator due to climatic reasons. Most of the coffee, however, is going to be consumed in the industrialised countries (e.g. Europe).

As water vapour and oxygen reduce the quality of coffee its packaging material consists of laminate with a number of layers made of different materials to prevent the diffusion of these substances through the packaging. This study investigates packaging where the barrier layer consists of aluminium foil (typically 6 to 12 µm, in this study 7 µm).

The functional unit for the coffee life cycle is defined as ‘to prepare one cup of coffee ready to drink at home’.

The impact assessment of coffee consumption includes a standard scenario for coffee made from ground or instant coffee with water and eventually milk as well as different spoilage, packaging disposal, and consumer behaviour scenarios.

The standard case assumes: average roasted coffee in a roastery with emission control, brewing the coffee or heating the water by an automatic coffee machine, normal user behaviour concerning coffee machine switch off, and PET/Al/PE bag.

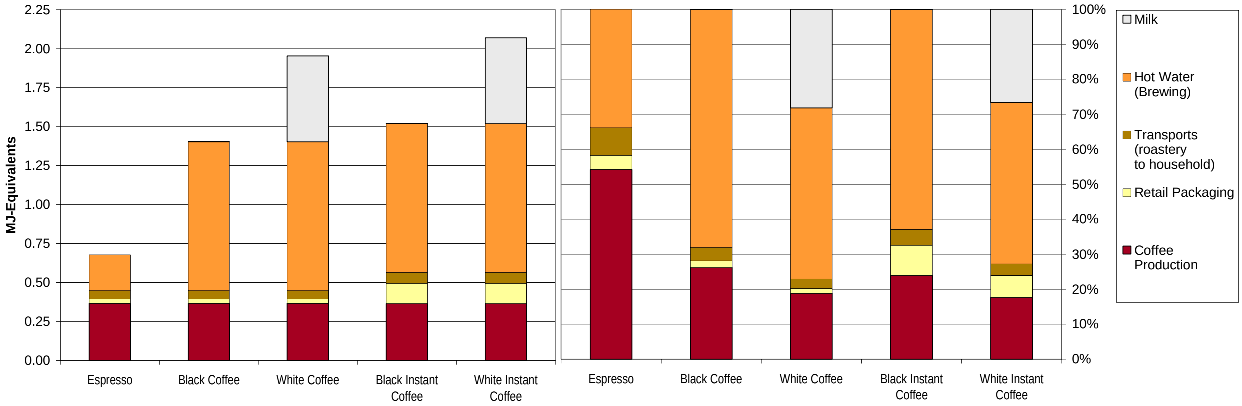

Figure 1: Results of the standard case for a cup of coffee with regard to the non-renewable cumulative energy demand. Left are shown the absolute values and on the right side the results are scaled to 100 %.

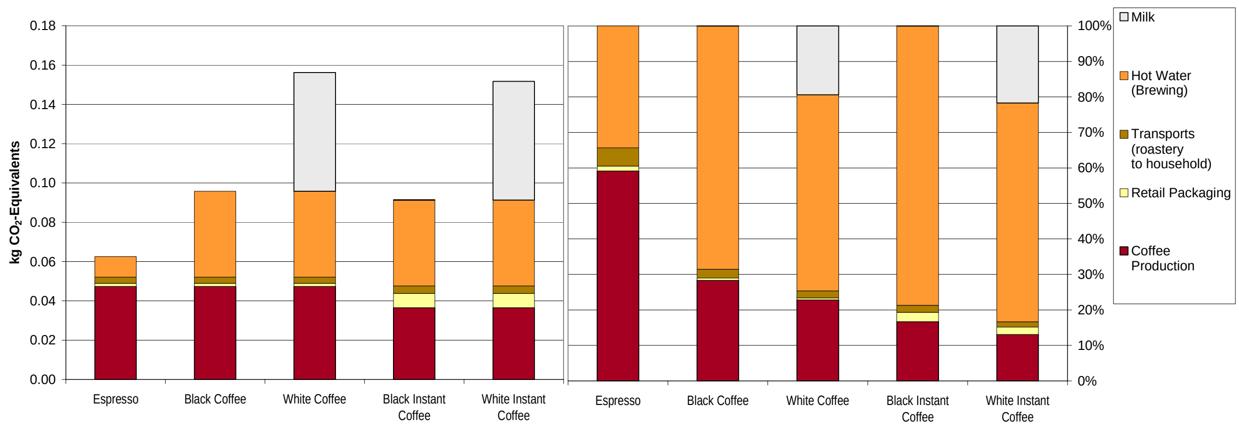

Figure 2: Results of the standard case for a cup of coffee with regard to the global warming potential. Left are shown the absolute values and on the right side the results are scaled to 100 %.

The study shows: the most relevant environmental aspects for a cup of coffee is brewing (i.e. the heating of water) and coffee production compared to transport and retail packaging which are of minor importance. Brewing and coffee production have a considerable impact share between 82 percent (ozone layer depletion, black instant coffee) and 99 percent (eutrophication, black coffee) In the case of white coffee the milk added is of great environmental relevance. The instant coffee in the one-portion stick-pack needs more packaging material per cup of coffee and leads, as a consequence, to higher shares of the retail packaging in all indicators. On the other hand: a one-portion stick-pack can prevent spoilage or over-consumption, and even when in this case hot water is also wasted resources related to coffee production can be saved.

A sensitivity analysis was conducted regarding the following parameters: brewing behaviour, i.e. normal (75% water excess) vs. economical (10%) resp. negligent (150%), brewing device (coffee machine vs. kettle), spoilage (no leftovers vs. 33% spoilage of coffee in case of ground coffee resp. hot water in case of instant coffee), packaging disposal (incineration vs. landfill), grocery shopping (average distances vs. urban resp. countryside scenario), adding up: best case / worst case.

The sensitivity analysis has shown the following results: the influence of packaging disposal is very small due to the general low influence of packaging. In contrast, the brewing behaviour is highly relevant for the environmental impact of a cup of coffee. That applies similarly to the type of heating device – i.e. using a kettle or an automatic coffee machine. Spoilage leads to a significant increase of all indicators. Under the spoilage scenario the coffee from one-portion stick-packs has a better environmental performance concerning all indicators, because in case of instant coffee spoilage of hot water and in case of ground coffee spoilage of prepared coffee has been predicted. Regardless of urban or countryside distances, grocery shopping has low impact.

In the best case scenario a kettle is used to prepare the coffee, the user behaves in an economic way regarding the brewing, the coffee packaging is incinerated resp. recycled (cardboard box) and the urban transport scenario is chosen for bringing the coffee from the supermarket to the household. In the worst-case scenario a coffee machine is used, the user behaves in a negligent way (switch-on time 24 h/d), the coffee packaging is landfilled and the countryside transport scenario is chosen.

Conclusions for the consumption of coffee: the most important factors concerning the environmental impact from the whole supply chain of a cup of coffee are the brewing of coffee, its cultivation and production, and the milk production in case of white coffee. The optimisation potential in the cultivation and production of coffee was not analysed. Against this background, the study highlights consumer behaviour and packaging related measures to reduce the environmental impact of a cup of coffee:

- Economic user behaviour, e.g. switching the machine on only when needed and reducing the stand-by usage.
- Using a kettle instead of an automatic coffee machine contributes to the reduction of electricity consumption, however, convenience and coffee experience aspects may not always allow to substitute a kettle for a coffee machine.
- Reducing leftovers of brewed coffee and hot water by preparing the coffee on a cup per cup basis. This avoids wastage of coffee in its drinking form including all the previously resources needed to produce and allocating the coffee and wastage of hot water.
- Minimising the amount of packaging – the cardboard box for the instant coffee packaging is not to be neglected in view of some indicators.
- Optimising the amount of packaging by choosing adequate packaging sizes.

Concluding remarks: Packaging has an environmental impact, though low, in relation to those along the full life cycle relevant to evaluate the sustainable consumption of drinking coffee. While single serving packagings normally needs more packaging per filling, taylor-made packaging, on the other hand, can reduce spoilage, thus improving overall resource efficiency along the food supply chain. However, compared to the reduction potential of other measures (e.g. economic coffee machine utilisation) packaging is not considered to be of primary importance for this type of product. Consumer's behaviour influences the environmental impacts of coffee consumption much more than the type of common packaging.

Case Study: Deep Frozen Spinach

The life cycle of spinach encompasses the whole food supply system from the cultivation of spinach to the preparation of frozen spinach in the kitchen ready to eat. The process steps for deep frozen spinach production are: cultivation, harvesting, transport by lorry, sorting, dry purification, washing, blanching, and quick-freezing. Spinach is frozen within two or three hours after harvest and has, then, to be stored and transported at a temperature of at least minus 18°C. The cold chain consists of three different cold stores (at the processing plant, in a storage warehouse, at the regional distribution centres), the supermarket and refrigerated transports. At home spinach can be stored in freezers up to almost two years.

Packaging of frozen spinach is quite simple compared to the packaging of high processed products. The analysed packaging consists of a typically used linear low density polyethylene (LLDPE) bag.

The functional unit concerning deep frozen spinach in this study is 'the preparation of one kilogram of spinach ready to eat at home'.

The impact assessment of deep frozen spinach consumption includes a standard case with the following assumptions: an average production of deep frozen spinach, LLDPE packaging, refrigerated storage and transportation at minus 18°C, domestic storage for 180 days in a B-class freezer, cooking spinach for ten minutes with an electric stove and the European electricity mix.

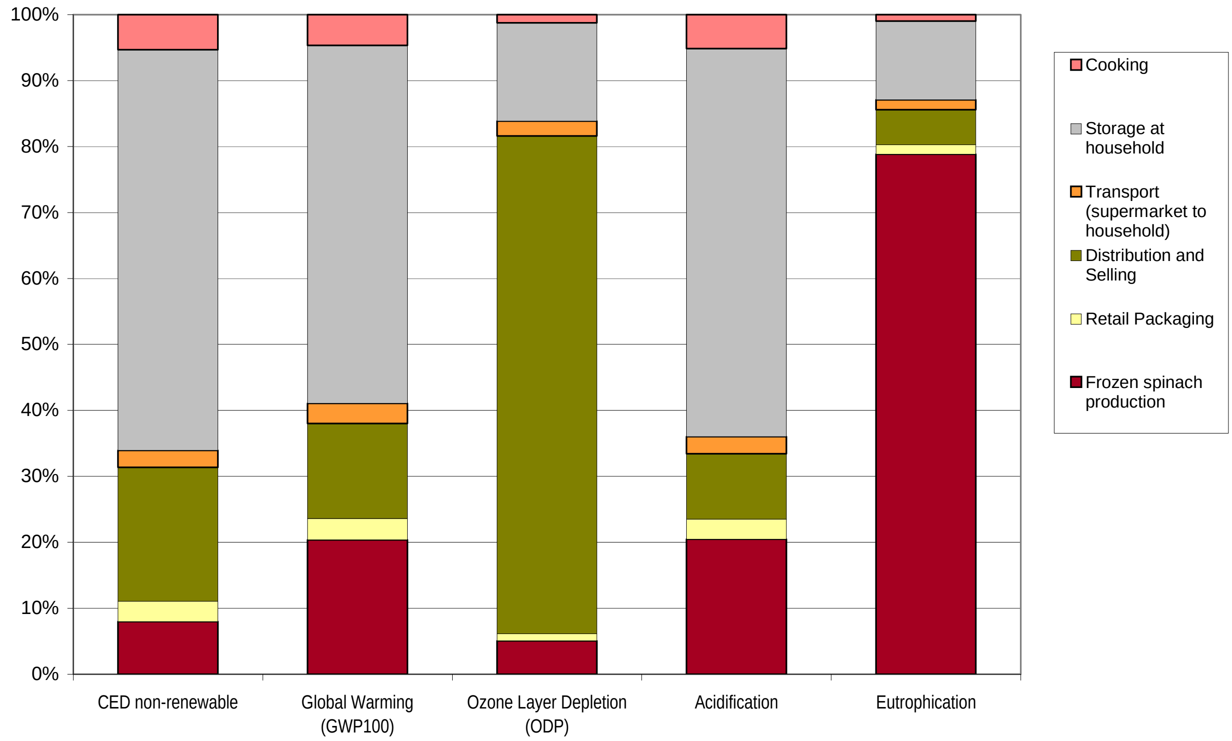

Figure 3: Results of the standard case for a pot of spinach with regard to the selected five indicators. The results are scaled to 100 %.

The study shows: the most relevant aspect regarding the life cycle of deep frozen spinach is both the cooling (storage at home and during distribution and selling) and the spinach production – compared to retail packaging, transport (from the supermarket to the household) and cooking which are of minor importance. Keeping spinach deep-frozen is, due to the long storage time, the most energy consuming process and responsible for most environmental impacts in all indicators except for eutrophication.

The sensitivity analysis compares modified parameters – e.g. chilled spinach with/without a 30 percent spoilage, A++ and C class freezer, gas cooking, packaging disposal in a landfill side instead of incineration – to the standard scenario.

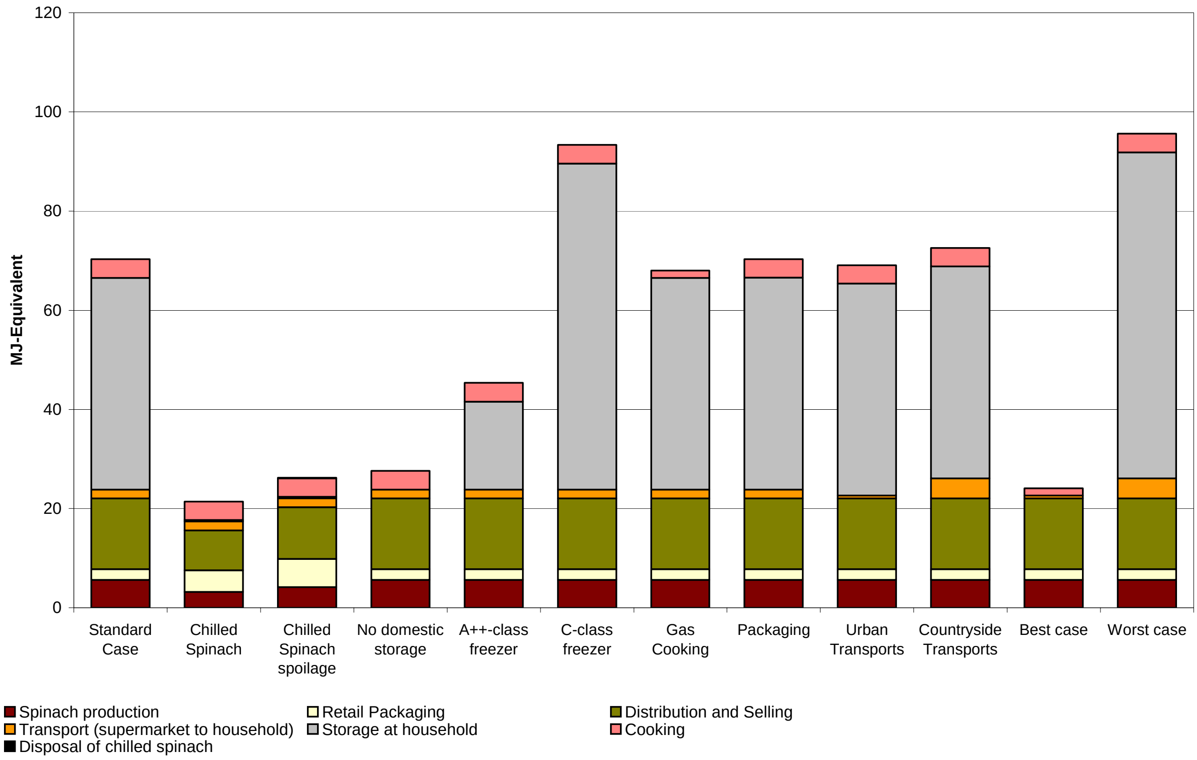

Figure 4: Sensitivity analysis with regard to non-renewable cumulative energy demand.

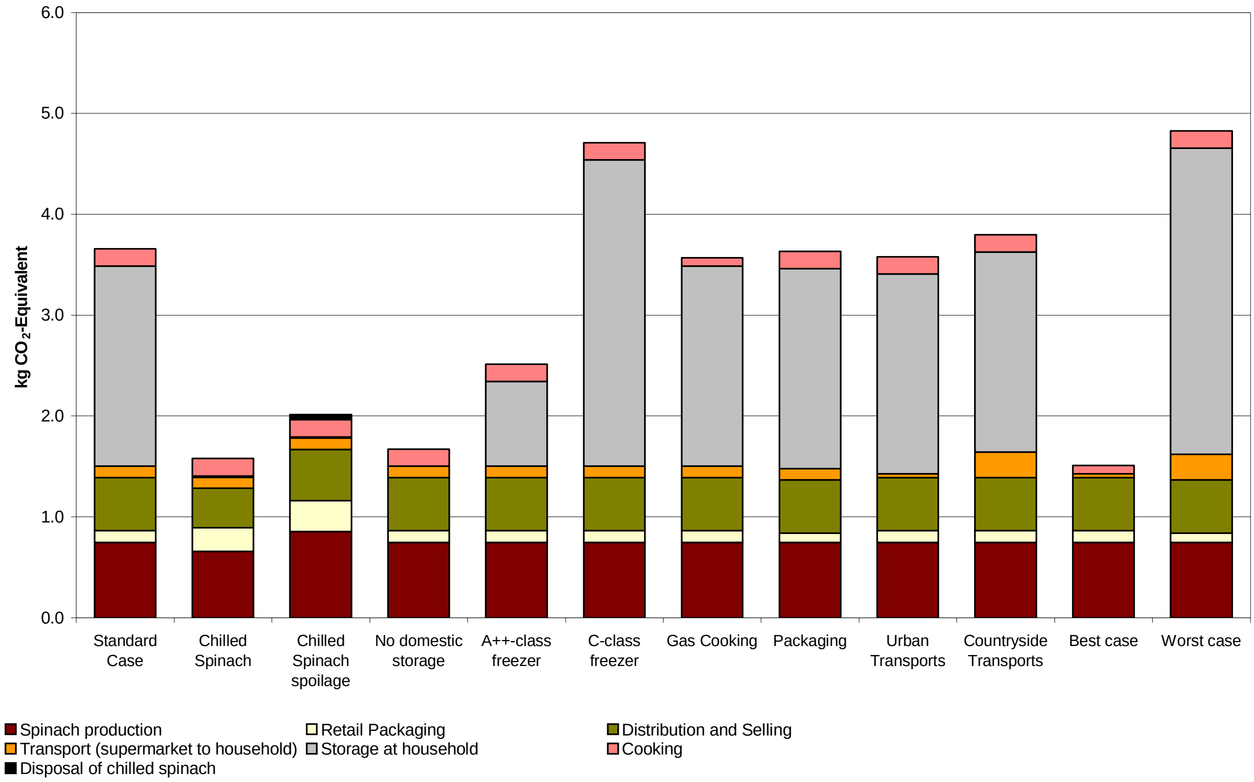

Figure 5: Sensitivity analysis with regard to global warming potential.

The sensitivity analysis has shown the following results: Chilled spinach (if no spoilage assumed) has lower impacts in all indicators considered mainly on account of the shorter storage time. The influence of packaging in the results for chilled spinach is between 3.2 percent for ODP and 54.2 percent for fresh water aquatic toxicity mainly due to the disposal of polypropylene. The domestic storage time is the most sensitive parameter in all indicators. When frozen spinach is consumed directly after buying the impact in cumulative energy demand decreases about 61 percent compared to the case where spinach is kept for 180 days. The use of an A++ class freezer leads to savings in energy demand and global warming potential of about 30 percent. The use of a gas stove instead of an electric one has positive effects except for ozone layer depletion due to emissions at gas gathering. The disposal of packaging has practically no influence on the results because of the low share of packaging in the total environmental impacts. Means of transport and shopping distances are of limited importance.

The best case consists of no domestic storage, usage of a gas stove, packaging is disposed in incineration and for grocery shopping the urban scenario is taken. The worst case applies to 180 days of storage in a C-class freezer, usage of an electric stove, landfilled packaging and countryside grocery shopping.

Conclusions for the consumption of spinach: The most relevant factors concerning the environmental impact from the whole supply chain are, for most indicators, storage of deep frozen spinach at home, refrigerated storage and transportation in the cold chain, and spinach production. As a consequence the most relevant measures reducing environmental impacts is to minimise the storing time of deep frozen spinach at the household and the use of efficient electrical household appliances.

With the application of hydrocarbons and CO_2 as refrigerant in distribution and selling points, the environmental impacts concerning ozone layer depletion can be decreased in future. Even if the cold chain improves, deep frozen spinach always needs to be kept frozen. Therefore the storage of deep frozen spinach remains the issue with the highest impacts in some indicators.

With regard to the impacts of packaging in the life cycle of deep frozen spinach it is to say that they are small and not of primary importance. In case of chilled spinach the share of packaging to the environmental burdens are more significant in some indicators. The chilled spinach has a much lower density. Thus, a higher specific amount of packaging compared to the product packed is necessary. Furthermore there is a lower impact from other processes (shorter storage time, no blanching, no freezing) which also leads to a higher share of packaging in the life cycle of chilled spinach.

Case Study: Butter

The life cycle of butter encompasses the whole food supply system from the milk production to the storage of butter in the consumer’s fridge. The process steps range from the separation of raw milk into low-fat-milk and cream to the pasteurisation of cream, cooling, ripening, and churning.

In this study conventional butter without any ingredients (e.g. salt) is considered. Butter is stored and transported under chilled conditions. The cold chain consists of one cold store, the supermarket and refrigerated transports. At home butter can be stored in fridge up to one month, but some consumers may freeze and store butter for a longer period.

Butter has to be wrapped in a greaseproof material that is impervious to light, flavouring and aromatic substances. The analysed packaging consists of three layers (aluminium foil, synthetic wax and paper). The packaging systems shown in this study represent the flexible packaging of one butter cube of 250 gram and 15 gram, respectively.

The functional unit concerning butter in this study is ‘the provision of one kilogram of butter ready to eat at home’.

The impact assessment of butter consumption includes a standard case with the following assumptions: average production of butter (i.e. 22.5 litres of milk to produce one kg of butter), packaging is incinerated, industrial and commercial distribution: refrigerated storage and transportation between 0 and 4°C, domestic storage: 30 days in fridge, no spoilage.

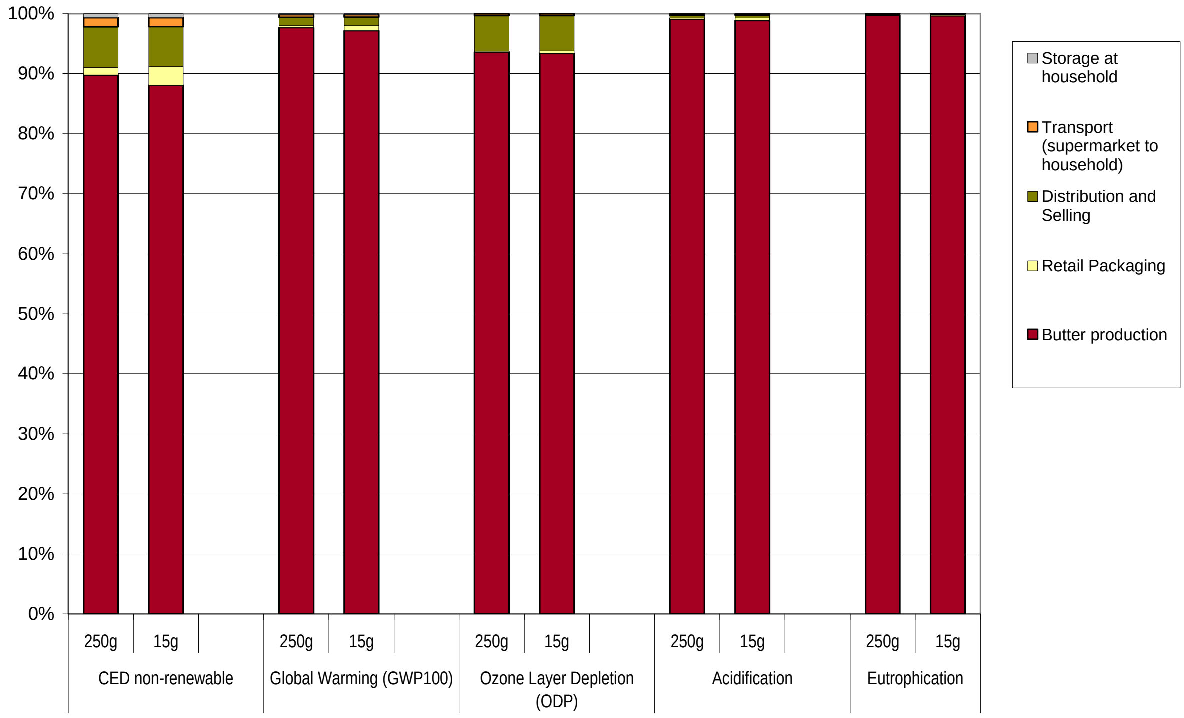

Figure 6: Results of the standard case for butter with regard to the selected five indicators. The results are scaled to 100 %.

The most relevant aspect regarding the life cycle of butter is butter production where the provision of milk dominates the results. Regarding global warming potential methane and dinitrogen monoxide emissions of milk cows are most relevant. Regarding acidification and eutrophication fertilisation during livestock husbandry is responsible for most burdens. The distribution and selling stage has a not negligible influence to the indicators CED and ODP. The reason is that the storage in supermarkets is quite energy intensive compared to the other processes and therefore responsible for most impacts in the distribution and selling stage regarding CED. Most impacts in case of ODP originate from emissions of refrigerants during storage and transportation of butter.

With regard to all calculated indicators the impact of packaging varies between 0.05 percent for eutrophication and 3.4 percent for human toxicity in case of the 250 gram packaging system. If butter is served in smaller amounts, the influence of packaging increases for all indicators due to the higher amount of packaging material used to pack one kilogram of butter (0.13 percent in case of eutrophication and 9.2 percent in case of human toxicity). In general, the environmental impact of packaging is of minor importance compared to butter production and distribution and selling.

Influence of transportation packaging for the butter cubes is less than 0.1 percent to the whole life cycle of butter consumption.

The sensitivity analysis compares modified parameters to the standard scenario. Modified parameters are 20 and 25 litres of milk instead of 22.5 litres, no storage resp. 180 days in freezer and 30 days in fridge, landfill of used packaging, urban and countryside shopping instead of an average distance, 33 percent spoilage and a best and worst case scenario.

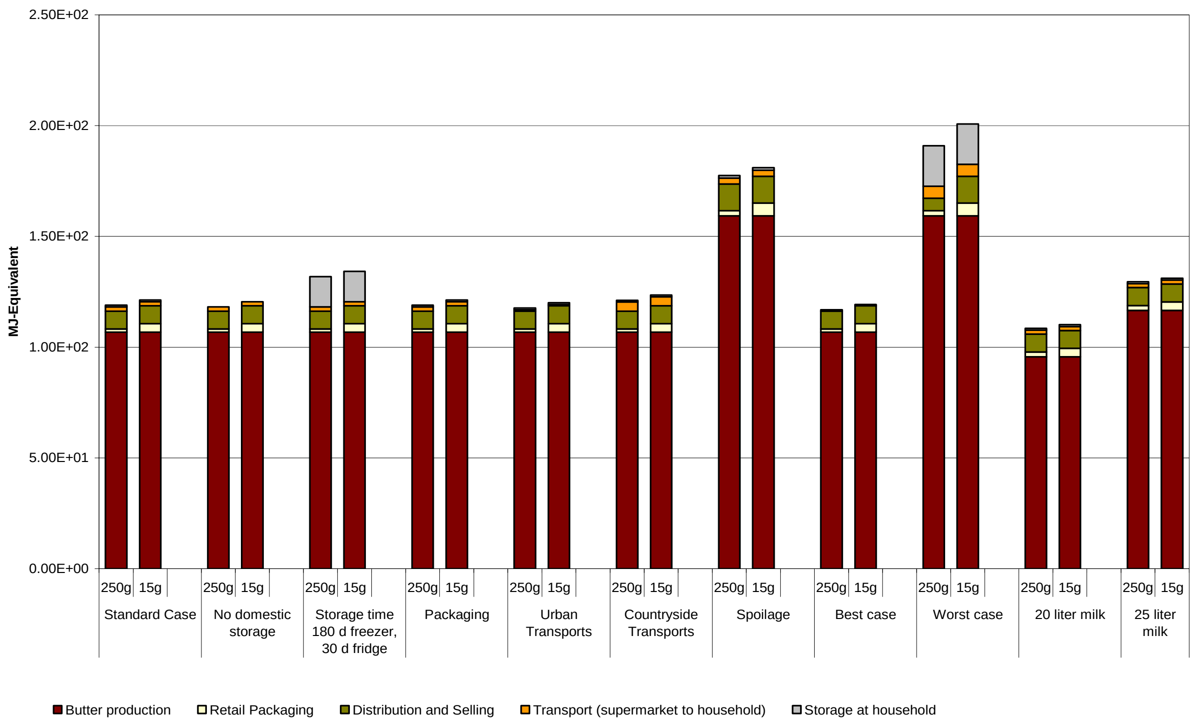

Figure 7: Sensitivity analysis with regard to non renewable cumulative energy demand

The sensitivity analysis has shown the following results: Storing butter in the fridge up to one month has no relevant environmental impacts. More important is the storage of butter in the freezer due to the higher electricity consumption and longer storage time. The kind of disposal of the packaging system has practically no influence on the results. Grocery shopping is of limited importance no matter which means of transport are used or which distances are regarded. Spoilage is of great importance: a spoilage of one third results in an increase of the impacts of about 49 percent in case of all indicators calculated.

The best case consists of no domestic storage, packaging is disposed in incineration, for grocery shopping the urban scenario is chosen and there is no spoilage of butter. The worst case applies to 180 days of storage in a freezer and 30 days in a fridge, landfilled packaging, the countryside grocery shopping scenario and a spoilage of 33 percent. Differences between the worst case and the standard scenario originate mainly from the spoilage scenario and the domestic storage process. Differences between the best-case scenario and the standard scenario are very small because butter production is not influenced and no spoilage was assumed for the standard case.

Unsurprisingly, the less milk is used to produce butter the lower are the environmental impacts in all indicators.

Conclusions for the consumption of butter: the most relevant factors concerning the environmental impacts from the whole supply chain are, for most indicators, the butter production, spoilage, domestic storage in case of the freezer scenario and refrigerated storage and transportation in case of ODP. As a consequence the most relevant measures reducing the environmental impacts would be the optimisation of the milk and butter production. Another important factor is the consumers' behaviour, i.e. the reduction of leftovers. A high share of leftovers results in higher impacts. The consumer can also influence impacts of domestic storage by reducing the storing time of butter in the freezer and by using an efficient freezer.

Regarding the impacts of packaging in the life cycle of butter it is to say that they are small and not of primary importance.

Summary

It should be the aim of every type of industry to minimize the environmental impacts directly related to their products. This study shows that in case of packaging industry this goal can only be reached if also aspects indirectly influenced by the product are taken into account. Thus, the packaging industry does not only aim to improve the production process of their packages, but also to provide packages whose functionality helps to reduce other more relevant environmental impacts in the life cycle. Depending on the product tailor-made packaging may also help to increase overall resource efficiency.