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Chapter 12

# Life Cycle Assessment Method – Tool for Evaluation of Greenhouse Gases Emissions from Agriculture and Food Processing

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Additional information is available at the end of the chapter

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**Abstract**

The chapter focuses on the use of the Life Cycle Assessment method to monitor the emission load of foods from different systems of farming production. The products of the conventional and organic farming production intended for public catering are compared within the SUKI and UMBESA international projects. Conventional farming is mainly characterized by high inputs of mineral fertilizers, chemical pesticides, the use of hormones and stimulants in animal husbandry. It is a system based on the highest possible yields without respecting the natural principles of nature. Conversely, organic farming is a system of production established by the legislation that respects fundamental natural cycles, such as crop rotation, ensures welfare of animals, prohibits the use of fertilizers, pesticides, and other substances of synthetic origin. However, lower yields are a big disadvantage. In the Czech Republic, only about one tenth of the agricultural fund is currently used for organic farming. Arable land constitutes only about 10% of the total area of agricultural land, other areas are mainly grasslands and orchards. The work primarily aims to answer to the question whether the selection of foods may contribute to decrease in greenhouse gas emissions, which is a part of the objectives of many policies. Besides the comparison of agricultural production, processed and unprocessed foods, local and imported foods and fresh and stored foods were compared as well. The Life Cycle Assessment (LCA), which is used to assess environmental impacts of products and services throughout their entire life cycle, was used to quantify the emission load. This method may be briefly characterized as a gathering of all inputs and outputs that take place during the production in the interaction with the environment. These inputs and outputs then also determine the impact on the environment. The LCA consists of four successive and iterative phases: This concerns the definition of objectives and scope, inventory analysis, impact assessment and interpretation of the results. The LCA was originally developed for the assessment of impacts of especially industrial products. Certain methodological problems and deficiency, which bring a level of uncertainty of the results, have been caused by its adaptation to agricultural product assessment, but this method is still recommended for comprehensive assessment of environmental impacts of agricultural production and the comparison of different agricultural products. In this study, a Cradle-to-Gate assessment was performed, which means that the impacts of products (in this case the emission formation) were evaluated only to the delivery of foods to public facilities, further treatment and waste management was not assessed. About 20 most frequently used foods for school catering facilities were compared. The results of the project confirm the general assumption about the less emission load of unprocessed, fresh and local products. It may not clearly state that products from organic farming produce less emissions when comparing agricultural systems. It always depends on the particular crop. The absence of synthetic substances such as fertilizers and pesticides reduces the emission load of organic farming, on the other hand, a higher number of mechanical operations and especially the lower income clearly increase the emission burden, therefore, in several cases, lower emission loads of crops were achieved using the conventional farming system. However, less emission may be achieved within the organic farming system. Among 11 evaluated agricultural products, 8 organic products and only 3 conventional ones go better. The situation is different regarding the following phases of food production, processing and transport. The transport phase significantly worsens the environmental profile of organic foods, because transport distances are too far due to insufficient processing capacity and underdeveloped market networks, and often exceed the emission savings from the agricultural phase. On the contrary, conventional foods are carried within relatively short distances, therefore the final emission load of conventional foods is in many cases fewer than the load of organic foods. This fact is also confirmed by the result of the study, because among 22 evaluated foods, organic food goes better in 11 cases and conventional food in 11 cases as well.

**Keywords:** LCA, conventional farming, organic farming, greenhouse gases, food

## 1. Introduction

Currently, agriculture is one of the largest anthropogenic activities with global impact. The area of agroecosystem that covers about one third of the landmass [1] is directly related to the need of humans to survive and it follows the population growth to a large extent. With the growing population curve, the pressure on natural habitats and their conversion to agricultural land and intensification of farming on existing agricultural land also increases. Since the population growth continues very rapidly and also the consumption of meat, respectively animal products, and the energy consumption in agriculture increase, we cannot expect that in the foreseeable future, a spontaneous reversion of the trend of increasing environmental load will come [2].

The environmental load increase impacts the soil, water, biodiversity and, last but not least, the atmosphere. Climate changes and anthropogenic contribution to them have become a frequently discussed issue in recent years. It is not clear yet to what extent these changes are natural and to what extent they are influenced by human activities. Many questions have not been answered yet and the discussion on whether the climate change is determined by natural evolution or negative consequences of human activity is still held [3]. Just the anthropogenic share of changes, especially in terms of GHG (Greenhouse gases) emission production, may be regulated while this activity is one of the priorities of sustainability.

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Climate changes have a significant impact on agricultural systems in the world and can be a crucial factor in ensuring sustainable food production. [4] states that, within the European Union, the largest polluters are energetics, which releases 27.8% of anthropogenic greenhouse gas emissions, transport with 19.5% and industry with 12.7%. Agriculture is with 9.2% in fourth place. Current agricultural trends tending to sustainability should establish more environmentally friendly ways while maintaining the ability of the population food assurance. In order to take steps in this direction, it is necessary to understand agricultural impacts and be able to quantify them. In the case of greenhouse gases, the accurate quantification is quite difficult. However, there are some methods that can help to implement it. One of the methodological tools is the Life Cycle Assessment - LCA. It can be used to quantify GHG emissions, respectively emission saving options. It is a transparent scientific tool [5] which evaluates the environmental impact on the basis of inputs and outputs within the production system [6]. Additionally, LCA analysis currently offers (as one of the few tools) a comprehensive approach to assess the environmental effects [7]. A very valuable tool is LCA analysis thanks to its ability to incorporate and compare different farming systems, their individual processes and products and most of their environmental impacts [8].

Considering the choice of farming system, respectively changes within particular farming systems, as a tool for mitigation, we need to quantify their total impact first and to find the most problematic areas in terms of emissions that can provide space for an effective change. The choice of farming system could be one of the ways to reduce the anthropogenic share of GHG emissions while organic farming seems to be one of the ways. In the last decade, organic farming has become an important element in the environmental friendliness policy and the policy of quality of food in Europe because, inter alia, it reduces the use of synthetic fertilizers and other chemicals such as pesticides [9]. However, mitigation can be achieved also within conventional and integrated farming systems and within food production in general. Reduction of emissions and environmental load in general is a necessary way to long-term sustainability within current population conditions.

## 2. Literature search

### 2.1. Climate change and agriculture activities

Anthropogenic activities have a very strong impact also on the environment. With increasing population curve, globalization, technological progress and higher consumer demands, also environmental pressure and environmental impacts grow. There are many impacts from impacts on water, soil, biodiversity to the impacts on the air. Just the anthropogenic air pollution and its relation to climate changes is a big current issue.

Agriculture is ranked among the five major anthropogenic activities contributing most to the production of greenhouse gases. Global GHG emissions from agriculture reach values from 5,1 to 6,1 billions tons of $CO_2$ equivalent [10]. [11] sets out the share of emissions of greenhouse gases ($CO_2$, $N_2O$ and $CH_4$) from particular fields of human activities, while his findings indicate that agriculture in 2000 contributed to the anthropogenic emissions with 13.5%. More than one third of agricultural emissions are field emissions (especially $N_2O$), methane ($CH_4$) makes up about one third. Also [12] states that agriculture contributes to the worldwide emission production with the share of 10-12%, while until 2030, we can expect an increase of even half these values [13]. Agriculture is a significant emission producer in the EU also according to [14]. The total share of GHG emissions from agriculture within the EU-27 was 10.1% in 2011 [15]. We can find similar values also in the paper by [16] who states that this share within the EU-15 was 10.2% in 2009. In the Czech Republic, the share of agricultural emissions in total greenhouse gas emissions is calculated at 6.42% [17].

According to [18], 29% of emissions produced within the EU is related to the food production. However, these emissions arising within food production are related not only to the field cycle but also to the production of fertilizers and agrochemicals, processing or all process transport. [18] sets the share of food production to anthropogenic emissions to 22-31% while the most significant proportion (15%) is related to transport.

[19] also stated the high dependence of agriculture on non-renewable materials and to a great extent, the resulting increased GHG emissions production. Agriculture produces emissions in many ways. For example, $CO_2$ is released during the consumption of fossil fuels or within reduction of organic matter content in the soil. $N_20$ is released as a result of fertilizer application, $CH_4$ from the digestive tract of some livestock species. We can conclude that the amount and composition of our diet reflect the specific features of particular technological processes in agriculture and thus the different GHG emission production. Therefore, the change in the way of nutrition in industrialized countries can be extremely important to ensure sustainable development (admittedly conditional on the stabilization of anthropogenic GHG emissions) [20].

### 2.2. Farming systems

Production systems have their own characteristics and can be categorized into groups e.g. according to density and the resulting impact on the environment. Conventional farming systems are commonly widespread, alternatively, there are integrated and organic farming systems.

#### *2.2.1. Conventional farming*

Conventional farming is the most common way of farming in agriculturally advanced countries. Its main objective is to maximize production. Other farming aspects are secondary. Conventional farming is implemented in various intensity degrees. Environmentally friendly processes beyond the ordinary laws are not enforced and monitored. Still, conventional farmers can implement these processes and farm in accordance with environmental protection. However, the European Union introduces a number of rules and legislative provisions for conventional farming leading to limiting inputs in order to protect the environment. On the contrary, in its extremely intensive forms, the conventional farming often leads to excessive environmental damage. The precision farming is a technologically advanced form of conventional farming that reduces environmental load to some extend through more efficient and optimized inputs.

### 2.2.2. Integrated farming

Integrated farming is a kind of an intermediate step between conventional and organic farming systems, originally based on integrated plant protection and extended to other agrotechnical processes. Its objective is the sustainability of farming system and it is largely focused on procedures friendly to the environment. However, unlike organic farming, it is not strictly limited by legislation and it is possible, if necessary, to apply procedures that are forbidden within organic farming (e.g. the use of some agrochemicals).

### 2.2.3. Organic farming

Organic farming is a special kind of farming that cares about the environment and its particular components through restrictions or bans on the use of substances and procedures that burden the environment or increase the risk of contamination of the food chain. Within livestock breeding, it ensures their behavioural and physiological needs in accordance with the requirements of specific legislation. It becomes an environmentally friendly alternative to other farming systems [21]. The main goals of organic farming include:

- Maintenance and improvement of soil fertility.
- Genetic resources protection and biodiversity maintenance.
- Preservation of landscape features and their harmonization.
- Water management, keeping water in landscape and the protection of surface and groundwater against contamination.
- Efficient use of energy, focusing on renewable resources.
- The pursuit for maximum nutrients recirculation and a prevention of the entry of extraneous substance into agroecosystem.
- Production of quality food and raw materials.
- Optimization of life for all organisms, including humans.

Organic farming systems create more potential to reduce greenhouse gas emissions than conventional. The biggest difference is due to the absence of chemical fertilizers. The Farming Systems Trial at Rodale Institute, an American long-term research comparing organic and conventional agriculture, states that the introduction of organic farming nationwide in the USA would manage to reduce $CO_2$ emissions by up to a quarter due to increased carbon sequestration in soils [22]. The disadvantage of organic farming is less production per the area unit that increases the unit emission load. [23] states that yields of organic farms are on average 17% lower than within conventional farming systems. The impact of organic system on the mitigation is usually measured per the area unit in order to enhance the objectivity. However, it is important to convert it also to the production unit.

### 2.3. A Life Cycle Assessment

The aim of the assessment of the effects of agricultural products on the environment is to evaluate their impact on environment sustainability [24], especially in terms of food consumption patterns [25]. As stated by [26], the system sustainability can be evaluated on the basis of inputs and outputs and their conversion to $CO_2$e. [27] states that the measurement of GHG emissions suffers from certain inaccuracy. The reason for this error is that emissions in agriculture are influenced by complex biological processes with a wide range of variables.

There are some suitable methods to assess environmental impacts of agricultural activities [28] such as Life Cycle Assessment (LCA), Ecological Footprint or Emergy Analysis. [29]. The LCA method may be briefly characterized as an assessment of all inputs, outputs and possible impacts on the environment during the entire life cycle [30]. LCA analysis is a tool that enables to assess environmental impacts within the product life cycle. Social or economic aspects may be included as well, however, the calculation of their impacts has only just begun [31] and the main focus is on the environmental component which evaluates, according to [32], the environmental impact of a product based on the assessment of the material and energy flows, that the monitored system shares with its surrounding space (environment).

[33] states that the LCA is an appropriate instrument because it enables to express the relationships between the food production, transport and production of $CO_2$.

With the LCA analysis, the impact categories - the impact on climate, water pollution and air pollution - are mostly evaluated. Whereas, impacts such as biodiversity or pesticide toxicity are seldom evaluated because of methodological problems [34]. The LCA study consists of four basic stages: Definition of objectives and the scope, Inventory, Impact assessment and Interpretation [32].

#### *2.3.1. Goal and Scope definition*

In the first stage of the LCA analysis, it is necessary to define the objective and the scope of the paper before the actual start [35]. The study goal and scope definition determine the next procedure character and the circumstances in which the study outputs are valid [32]. [36] requires to establish a study goal and scope while the study scope means to determine the product system, the functional unit and system boundaries, to determine allocation rules, the assessment methodology, hypothesis and limits and data quality.

In the objectives of the study, there must be clearly specified who it is addressed to, the reasons for the study and the intended use of the results [36]. This increases the transparency of the study and the comprehensibility of the context of the results since different recipients emphasise different aspects.

The study scope results form goals and is determined by financial resources of the ordering authority and the available time of the processor [5]. The study scope describes the most important methodological choices, hypothesis and limits [35] that are described below.

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*2.3.1.1. Function and functional unit*

To compare products (systems), it is necessary to define also the functional unit. The functional unit is described as a quantified performance of a product system which serves as a reference unit in a study of life cycle assessment [36]. It is an essential element which all study results are related to. It must be chosen so as to be easily expressible and measurable. The functional unit is the starting point for searching for alternative ways how to fulfil the function with a lower negative impact on the environment [5]. [37] states that the determination of functional units is as a crucial step especially when comparing systems with different levels of production per hectare such as conventional and organic farming system. [38] sees fit to set the production unit instead of the area unit as a functional unit. On the contrary, [9] recommends to involve both functional units into calculations and perform the calculations for both the unit area and the unit of production. This is confirmed also by [39] who states that LCA analysis outputs are usually set per the production unit. Some authors, such as [40], state that LCA outputs should by calculated in relation to the area unit allowing the better expression of environmental load carrying capacity. With the LCA analysis, we cannot perform both calculation methods and use the production unit as well as the area unit as a functional unit [2].

*2.3.1.2. System boundaries*

Each product system consists of a variable number of processes involved in the product life cycle. However, the product under consideration is often related to other processes that may no longer be important for the LCA study. The system boundary serves to the separation of essential and non-essential processes of the product life cycle. Since the choice of system boundaries significantly affects LCA study outcomes and in addition, its intensity and complexity, system boundaries should always be well considered and clearly defined. The choice of system boundaries is carried out with regard to the studied processes, studied environmental impacts and selected complexity of the study. Not-including any life cycle stages, processes or data must be logically reasoned and clearly explained [32].

Determination of system boundaries is always a very important step, especially in the area of food production and agriculture, where the clearly identifiable technological processes and systems meet the natural processes and procedures influenced by a number of factors [41]. The system boundary defines which unit processes will be included in the monitored system [36]. The system boundary definition virtually defines which life-cycle stages will be analysed (in the case the whole life cycle was not included) or what unit processes and elementary flows will or will not be considered. The system boundaries can be restricted to the processes within the farm [42], or can extend into other phases from pre-farming processes, through transport and storage, to the end user, respectively consumption. [43] states that although it would be desirable to include the entire product cycle, most studies of food production omit some phases, usually trade and other related sections. Their impact is mostly negligible in relation to e.g. the agricultural phase [44]. When comparing conventional and organic farming systems, we can also omit the calculation of load from buildings and infrastructure because there are only small differences between farming systems while slightly more noticeable difference is apparent within animal production [45].

System boundaries determine not only which processes will be incorporated into the product scheme, but also define the geographic and temporal scope of the study to determine its purview. Defining the geographical scope (local, regional, national, continental or global) or determination of the exact study location is important for the environmental aspects of various material and energy flows because their impacts may be different in different geographical conditions. E.g. due to different ways of development of power in each country, the environmental impact of power development and hence of energy consuming processes is different. Using unsuitable system boundaries or oversight of important factors such as the place and method of energy development can lead to false results.

*2.3.1.3. Allocation principles*

During the life cycle assessment, the study authors are very often confronted with the fact that the product system has at its end more than one output. In these cases, we use the allocation. Allocation means the assignment of the share of total environmental burden to particular outputs [32]. The Standard recommends to avoid the allocation whenever possible, e.g. by extending systems or sub-division processes [36].

In the case we cannot avoid the allocation using the above mentioned methods, the Standard proposes to use the allocation based on the physical principle such as weight or energy content of final products.

*2.3.1.4. Data quality*

The quality of data entering the LCA study is to be determined in view of temporal, spatial, technological, data sources (it must be determined whether primary data required or secondary data can be used), their accuracy etc. It concerns the determination of all requirements for the input data [5].

*2.3.2. Life Cycle Inventory*

The inventory tasks is to collect environmentally important information about relevant processes involved in the product system. Inventory collects information about unit processes at first and subsequently, an inventory of inputs and outputs of the system and its surroundings is carried out. The goal is the identification and quantification of all elementary flows associated with product system. Inventory analysis is the nature of the technical implementation of LCA studies. It is an essential part of a study, has high demands for data availability, practical experience in modelling product systems and, in the case of using database tools, it is necessary to master them perfectly and to understand their function [46]. The inventory phase principle is data collection that is used to quantify values of the elementary flows. This phase represents a major practical part of the LCA study, time consuming and with demands for data availability and author's experience with modelling product system studies [47].

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#### *2.3.3. Life Cycle Inventory Assessment*

The inventory results should be presented in clear form, how much and what substances from the environment enter the system and how much get out. These results serve for subsequent life cycle impact assessment [48]. The aim of the life cycle impact assessment is to measurably compare the environmental impacts of product systems and to compare their severity with new quantifiable variables identified as impact category. The impact categories are areas of specific environmental problems such as global warming, climate changes, acidification, eutrophication, ecotoxicity and others. Already in the phase of definition of the LCA study scope, it is necessary to describe what impact category will be applied and which of their environmental mechanisms will serve as a basis for impact assessment [46].

#### *2.3.4. Interpretation*

The outcome of the LCA study is a large amount of different values from the inventory as well as from the life cycle assessment. An important task for the study author is to sort the data and their appropriate and understandable interpretation [32]. The need for proper interpretation is also stated by [49] who states that on the basis of LCA outcomes, there are often taking steps with significant economic, environmental and other impacts, while there is the risk that incorrect and misleading interpretation of outputs can lead to a deepening of existing or creating new problems. Since the form of presentation of data often affects their meaning, the life cycle interpretation has become an integral part of LCA studies and gained some rules. On the general, interpretation of LCA consists of structuring data with regard to the most important processes or process groups and the most important substances, performing sensitivity analyses and evaluation of the uncertainties of the study, discussion of the data meaningfulness in relation to the study completeness and the input data quality, and the final summary and formulation of realistic recommendations.

## 3. Goal of the study

The main objective of the Czech - Austrian SUKI (Sustainable Kitchen) project was to assess the total amount of GHG emissions produced by public catering facilities.

These emissions originate both within energy consumption for the kitchen operation (ie. lighting, heating, ventilation, cooling, operating kitchen appliances, cooking process), but mainly in the food production, processing and transport to catering facilities. While direct energy consumption in the kitchen can be determined relatively easily, emissions from food production are unexplored areas in the Czech Republic. The project set the target to answer following questions using the emission quantification:

- What is the influence of the production method (conventional, organic) on the GHG emission production?
- What is the influence of the place of the food origin (region / outside the region) on the GHG emission production?

- What is the influence of the food processing method (raw, processed, fresh, frozen) on the GHG emission production?

By answering these questions, we can deduce the possibilities and limits of greenhouse gas emission savings without compromising the food quality which is also subject to the actual selection of foods, meals and a preparation process. The aim is to promote catering facilities on the path to sustainable production and at the same time to the food nutritional quality improvement. Through targeted food selection, they can take a step towards sustainable development and a healthy diet, contribute indirectly to the global reduction of greenhouse gas emissions while promoting regional organic farming.

## 4. Methodological procedure

In the first project stage, it is necessary to identify the most widely used ingredients heading for school catering facilities. For this purpose, we used annual lists of purchased raw materials from partner catering facilities that were processed by tabulating and from them, all the ingredients that made up at least 80% of the raw materials used kitchens during the year were selected. These lists also provide a good comparison between Czech and Austrian cuisines.

The second step and the focus of this chapter was to evaluate the emission load of individual foods from the list of most common foods. There was used the simplified Life Cycle Assessment method in which only the Climate change Impact category was assessed. Detailed description of the LCA methodology is shown in the literature review, the following text describes practical method implementation.Food emission load evaluation using the LCA method

### 4.1. Goal and Scope definition

On the basis of evaluation of consumption of involved catering facilities, 11 most commonly used products were selected. When work them into other raw materials, we can expand the list to final 22 products that heading for school kitchens. For each product, a comparative study focused on the comparison of organic and conventional versions, imports and regional variants was elaborated, if possible, the also a comparison of the fresh and stored product was made, as well as a comparison of different stages of processing. The results should serve as an answer to the question whether the selection of the food contributes to reducing greenhouse gas emissions. The target group are the chiefs of kitchens, school principals, cooks, diners, farmers, suppliers, as well as actors at the regional and national political level.

Evaluated systems were modelled with the cradle to gate principle, thus the product system of particular foods was terminated at the point of entry into the school canteen. The following presentation of food and related activities, as well as waste management of the product and its packaging materials were not included in the LCA. One kg of the final food was selected as a functional unit. In the case the allocation was necessary, the weight-economic allocation was used.

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### 4.2. Life Cycle Inventory

At this stage, it was necessary to collect the relevant data relating to the entire product system. The product system was divided into sub-processes: agriculture, processing and trade. For agriculture, inputs relating to the consumption of seeds, fertilizers, pesticides and fuel within agricultural operations for crop production, feed consumption, energy and fuel within the livestock sector were surveyed. Emissions from nitrogen fertilizer application within crop production calculated according to the methodology [50] and emissions from manure management in the livestock production, calculated according to the methodology [51], were integrated into agriculture. A general framework for crop and livestock products is shown in Figure 1 and Figure 2.

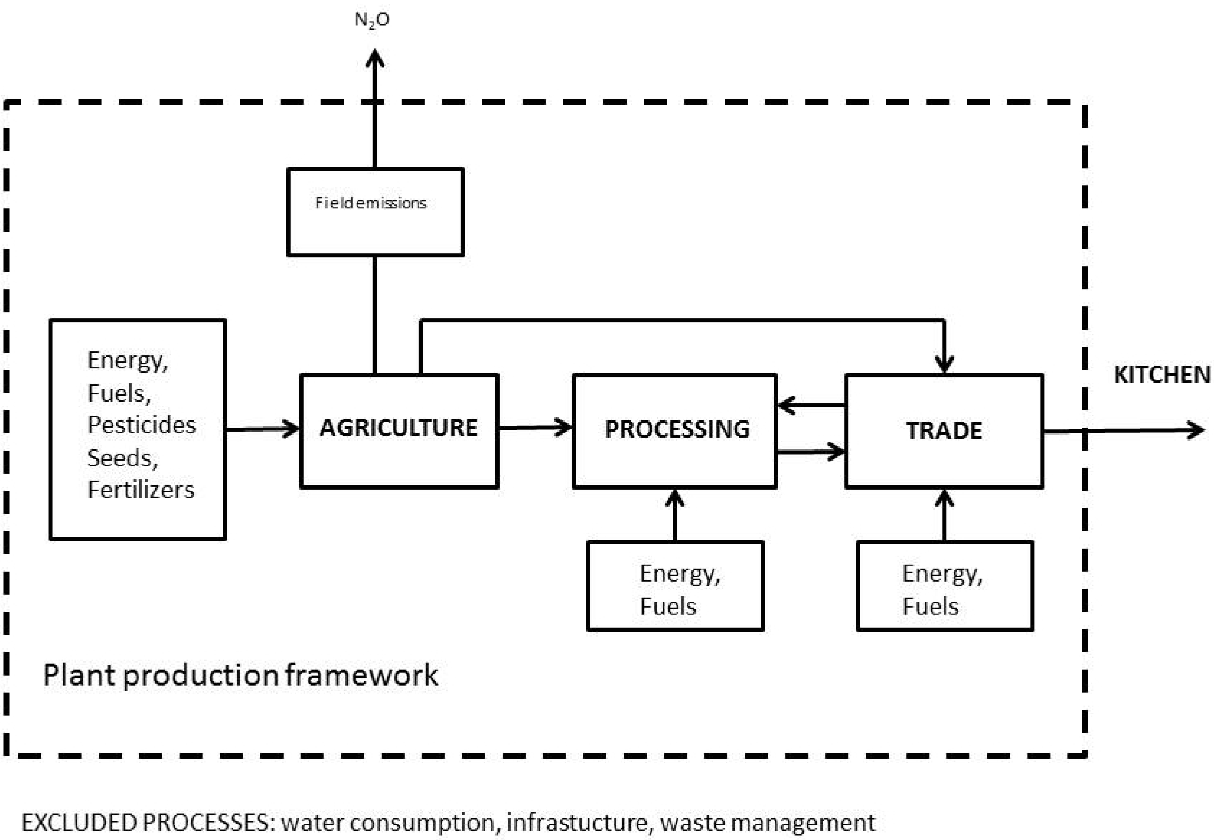


**Figure 1.** Framework of plant food product LCA

For processing, the data on energy consumption were collected, within the trade, it was travel distance, information on cargo and storage time of various foods. All data was obtained primarily from farmers, processors and traders, absent sufficient data, it was supplemented by data from available databases, especially the Ecoinvent database.

From a geographical point of view, regarding the data quality, the data corresponds primarily to the Czech Republic, secondarily to Central Europe. In terms of time, data corresponding to the term 2000 - 2012 were obtained, from a technological point of view, data corresponds to the widely used average technologies.

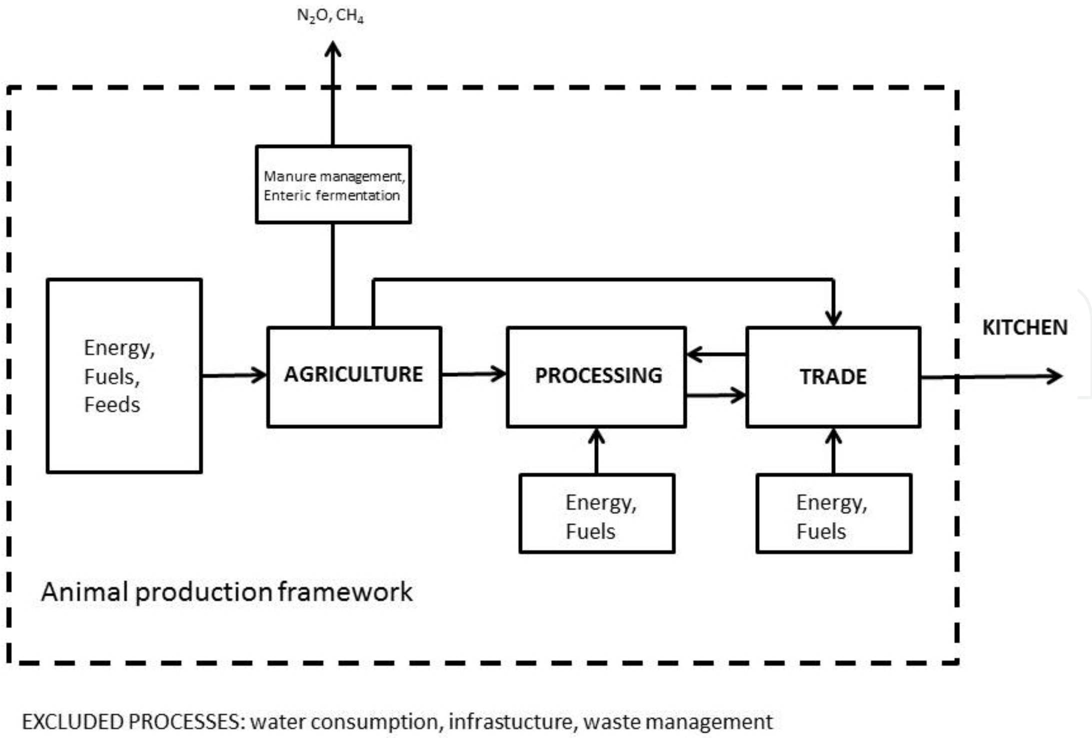


**Figure 2.** Framework of animal food product LCA

### 4.3. Life cycle inventory assessment

The results were calculated using the SIMA Pro software. To obtain the necessary results, the Recipe Midpoint (H) Europe method has been chosen as a characterization model. Results come from the climate change impact category and they are expressed in kg of a carbon dioxide equivalent ($CO_2$e).

### 4.4. Interpretation

Result interpretation and discussion is given below.

## 5. Results

Based on the analysis of the annual consumption of foods of participating catering facilities, there were 22 of the final products which constitute the largest food consumption selected.

### 5.1. Emission load in food production

#### *5.1.1. Agricultural phase*

A basic emission load resulting from agriculture involves the calculation of greenhouse gases in the field phase. In the context of comparing the formation of greenhouse gas emissions in

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the cultivation of selected crops and breeding of selected species within conventional and organic farming systems, the total greenhouse gas emissions with twelve agricultural products were observed. This total amount sum was divided into subgroups within crop production: agricultural engineering, fertilizers, pesticides, seed and field emission, and in the context of animal production to: feed consumption, manure management, and in the case of cattle on enteric fermentation.

In the case of crop production, the conventional farming system differs from the organic one in the total $CO_2$e emissions production as well as in the production within subgroups. Although the production of GHG emissions differs within particular subgroups, in total with most studied crops, the production of $CO_2$e is lower in the organic farming system. In the primary agricultural study, [52] monitored a set of crops including wheat, rye, potatoes, onions, carrots, tomatoes and cabbage, while the higher greenhouse gas emissions expressed as CO2e within the conventional farming system in the Czech Republic were found with all investigated crops except onions. The greatest differences were found with carrots and cabbage where the ecological variants produced almost 60% lower emissions than the conventional variant. The extension study [53] complements the study with the comparison of emission load of organic and conventional apples and rice, where the results showed almost the same burden for rice and in the case of apples, 33% lower emissions within organic farming. Another extension study [54] comparing garlic proves again 40% lower emissions when grown in the organic farming system. In conclusion, it can be summarized that in the context of plant production, eight of ten evaluated products were better as an organic variant, one raw material showed the same emissions in both variants and only one crop was better in the conventional variant. Results and emission savings are summarized in the Table 1.

| Group | Product | Organic* | Conventional* | save BIO |
|---|---|---|---|---|
| corn products | wheat | 0,4218 | 0,4606 | 8% |
| | rye | 0,2972 | 0,5364 | 45% |
| | rice | 0,6197 | 0,6266 | 1% |
| vegetables products | potatoes | 0,1256 | 0,1446 | 13% |
| | cabbage | 0,0329 | 0,0774 | 58% |
| | carrot | 0,0411 | 0,0987 | 58% |
| | tomato | 0,0671 | 0,0871 | 23% |
| | onion | 0,0997 | 0,0828 | **-20%** |
| | garlic | 0,2480 | 0,4306 | 42% |
| fruit products | apple | 0,0568 | 0,0848 | 33% |

*in kg $CO_2$e/kg of products

**Table 1.** Emission of GHGs from the plant production (agriculture phase only)

Comparative studies show positive and negative factors of organic farming which are mainly lower yields and specific agronomic rules. It coincides e.g. with findings by [55]. The organic farming is more agricultural operations intensive as compared with the conventional one. For most crops, emissions from production of one kg are higher due to more intensive agricultural technology (especially mechanical protection against pathogens), while the difference is even increased by generally lower yields in organic farming. Emission load within the agrotechnical phase in the organic farming system is increased also by some operations related to pre-seeding soil preparation. The possibility of reducing GHG emissions by changes in agricultural technology is highlighted e.g. by [56] who identifies the main potential for reduction within tillage.

The fundamental difference between the conventional and organic farming system in terms of GHG emissions is obvious within fertilization. While organic farming uses organic fertilizers (especially manure or slurry), the use of synthetic fertilizers within the conventional farming system increases significantly the share of emissions. This is stated also by [57] who gives synthetic fertilizer decrease as one of the main tools for reducing $CO_2$e emissions. From an economic perspective, the nitrogen in organic farms is financially much more demanding than industrially produced nitrogen. This is a powerful incentive to try to prevent losses and learn how to use recycling technology [58]. Timing and management of nitrogen application are crucial. Soil mineralization processes should deliver components to plants when the plants are most in need [10]. In conventional farming, GHG emissions are increased also due to the use of pesticides. In organic farming, this load is completely eliminated, respectively, transferred to the agrotechnical phase in the form of mechanical plant protection. However in total, it is a relatively low proportion of total emissions. [59] can see here another opportunity to save emissions.

Within plant production, in organic farming, there is space for reducing greenhouse gas emissions per the production unit and an increase in income, while maintaining the current input structure.

To compare the emission load of livestock products, several studies were carried out again. Initial work [61] compared load from conventional and organic cattle breeding without milk production. One kilogram of organic beef produced twice higher emissions than one kilogram of conventional meat. Another study [53] compared pork. Organic pork was again worse than conventional meat in terms of emissions. On the contrary, when comparing variants of milk, organic milk was a little emission-less burdensome than conventional milk. The latest from animal studies compared the production of eggs [62], where organic eggs produce almost 40% lower emissions than conventional eggs. Results and emission savings are summarized in the Table 2.

The higher emission load in organic farming systems is mainly due to technology of rearing and fattening when in the organic farming system, young ones are fed with breast milk while in conventional breeding, they are fed with feed. Production of breast milk causes significantly more emissions then production of crops for feed mixtures. Additionally, within conventional breeding, the emission load is divided among several products (meat, milk).

| Product | Organic* | Conventional* | save BIO |
|---|---|---|---|
| milk | 1,336 | 1,420 | 6% |
| egg | 0.219 | 0.383 | 43% |
| beef | 24,10 | 11,45 | **-110%** |
| pork | 6,643 | 5,143 | **-29%** |

*in kg $CO_2$e/kg of products(in egg study in kg $CO_2$e/egg)

**Table 2.** Emission of GHGs from the animal production (agriculture phase only)

### *5.1.2. Manufacturing phase*

Environmentally friendly farming systems that utilize anti-erosion measures, advanced methods of nitrogen management and other measures, have the potential to sequester carbon and reduce greenhouse gas emissions [63]. This creates a positive environmental potential which may however be discarded in the following, or vice versa agricultural stage preceding, parts of the food production process which could result in a significant increase in $CO_2$e emissions. [64] states that within cereal production, the production of fertilizers in the pre-farming cycle makes up 35% of total emissions, while the farm stage only 27%.

Importance of pre-farming and post-farming stage can be documented by the example of potato, where [65] states the production of 0.145 kg of $CO_2$e in the conventional and 0.126 kg of $CO_2$e in organic farming system per one kilogram of potatoes. However, if we take into account also other phases (especially the processing and transport), the load resulting from potato products in relation to potatoes grows significantly. For one kilogram of peeled potatoes in the Czech Republic, it is 0.262 kg of $CO_2$e in conventional 0.247 kg of $CO_2$e in organic farming systems. However, for the manufacture of chips, it is already 2.072 kg of $CO_2$e in conventional and 2.271 kg of $CO_2$ in organic farming systems per one kilogram of finished product. And in the case of mashed potatoes, even in conventional production, it is 3.201 kg of $CO_2$e and in organic production 3.192 kg of $CO_2$e. These findings suggest that the differences between the production systems are relatively small if we compare it to the difference in $CO_2$e emissions between processed and unprocessed products. Another important factor is also common transport distances. Their importance is higher with the processed products that are in their life cycle more transported (besides transporting raw materials, there is still transport of semi-finished products between processing units). The transport distance is also affected by the density of processing networks and infrastructure. The results of the finished material (see Table 3) in our study [53] showed that eleven of the 22 evaluated products have better results as a conventional variety and eleven products have better result as a organic variety. This indicates a lack of potential of a manufacturing and sale network for organic products.

| Group | Product | Organic* | Conventional* | save BIO |
|---|---|---|---|---|
| corn products | wheat | 0,4593 | 0,4699 | 2% |
| | rye | 0,3336 | 0,5495 | 39% |
| | wheat flour | 0,6463 | 0,5861 | **-10%** |
| | rye flour | 0,5080 | 0,6737 | 25% |
| | roll | 0,8100 | 0,7766 | **-4%** |
| | bread | 1,0431 | 1,0632 | 2% |
| | pasta | 0,7336 | 0,7020 | **-5%** |
| | rice | 0,6197 | 0,6266 | 1% |
| vegetables products | potatoes | 0,1931 | 0,1867 | **-3%** |
| | peeled potatoes | 0,2475 | 0,2624 | 6% |
| | puree | 3,1918 | 3,2009 | **0%** |
| | pommes | 2,2714 | 2,0718 | **-10%** |
| | cabbage | 0,0851 | 0,1151 | 26% |
| | carrot | 0,1158 | 0,1517 | 24% |
| | tomato | 0,1748 | 0,1802 | 3% |
| | onion | 0,1749 | 0,1285 | **-36%** |
| | peeled onion | 0,2428 | 0,1789 | **-36%** |
| fruit products | apple | 0,1273 | 0,1189 | **-7%** |
| milk products | milk | 1,4870 | 1,5603 | 5% |
| | yoghurt | 1,7390 | 1,8123 | 4% |
| meat products | beef | 24,5313 | 11,6510 | **-111%** |
| | pork | 6,7452 | 5,3083 | **-27%** |

*in kg $CO_2$e/kg of products

**Table 3.** Emission of GHGs from the final products

Besides transport distances, also the way of transportation has the influence. E.g. [63] states that significant energy savings could be achieved by rail preference which can reduce power consumption by up to half while emissions of greenhouse gases are reduced comparably. These factors, together with the production technology may, in some cases, eliminate emissions savings resulting from environmentally friendly management system. The principle of regionality which reduces unnecessary transport processes is thus superior to the principles of organic farming, since its failure may to reduce or completely eliminate the environmental potential, respectively, the emission savings resulting from organic farming,. Reducing the environmental potential can be demonstrated e.g. by the example of the production of bread in conventional and organic farming systems in the Czech Republic. Thanks to the low-volume technologies in production of bread in organic processing capacities, produced greenhouse gas emissions are much higher, so the positive effect of previous organic cultivating of wheat and flour production is eliminated [66]. Post-farming life cycle stages of agricultural products are very significant in terms of GHG emission production because within them, the emission savings generally made by organic farming in relation to conventional farming can be devalued. Assuming that the growing agricultural systems with arable land and permanent crops and grazing systems worldwide can sequester up to 200 kg C ha-1 year-1, the global carbon sequestration can reach 2.4 billion tons of $CO_2$e year -1. This minimum idea of conversion to organic farming would be able to lose 40% of global agricultural GHG emissions [10]. Environmentally friendly and organic farming systems are such an important tool for reducing greenhouse gas emissions.

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