SEGES INNOVATION

DAKOFO Dansk Korn & Foder

RAPPORT

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LCIA of Danish broad beans

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Table of Contents

1 INTRODUCTION....2

2 WORKFLOW....2

3 NOTES ON MODELLING....2

4 LCIA RESULTS....4

5 SUPPLEMENTARY MATERIAL....8

1 INTRODUCTION

Given the widespread use of the GFLI database, this project aims to generate additional datasets with relevance for Denmark. The datasets are calculated according to the GFLI methodology, but they have not been externally reviewed yet (as required by GFLI for approval in their database).

The selected datasets come from a priority list made after a few meetings between SEGES Innovation P/S, DAKOFO and its members, where a few key Danish “raw feed ingredients” and “processed feed ingredients” were shortlisted. This report focuses on the production of the following pulses (“raw feed ingredients”), grown via conventional and organic agriculture: broad beans (also known as fava bean, or faba bean).

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2 WORKFLOW

A brief description of the workflow:

- Primary and improved secondary data on broad beans cultivation in Denmark was collected by representatives from SEGES Innovation, using a broad list of data sources, using the GFLI data collection template for cultivations. Data collection followed the steps described in the project deliveries “Datainput til LCA” (in Danish).
- Primary and improved secondary data from SEGES overwrites the “default” data that is available in Agri-footprint 6.3 (AFP6.3), and missing data was filled in using the AFP6.3/GFLI methodology.
- Emission models describing emissions to air, soil and water are compliant with GFLI/AFP6.3 methodology
- LCIA impacts of broad beans were generated using ReCiPe 2016 Midpoint (H). See more details about the use of Recipe 2016 Midpoint (H) and EF3.1 in the supplementary material (“SM OpenLCA vs SimaPro”).

3 NOTES ON MODELLING

Key modelling parameters that require further specification (other than the well described AFP6.3 and GFLI methodology):

- The model uses AFP6.3 as the background LCI database.

- Crop residue modelling parameters (unless otherwise specified, the data is based on IPCC (2019), Table 11.1A and 11.2):
  - Broad beans:
    Slope and intercept: “Beans and Pulses”
    N contents in ABR and BGR: “Beans and Pulses”
    Ratio of BGB to AGB: “Beans and Pulses”

- FRACremove = 1.02%. (fraction of above-ground residues of crop T removed annually for purposes such as feed, bedding and construction). The value is calculated based on the ratio between removed straw and yields reported in Danmarksstatistik (codes: HST77 and HALM1; average value between 2020-2021), which is equal to 2.1%.

- Heavy metal uptake by the crop based on Delahaye et al. (2003) (see AFP6.3 methodology, Table 3-10): “pulses/lupine”.

- The cultivation of Danish broad beans does not (typically) use any manure, but only some PK mineral fertilizers. Therefore, the amounts of manure used for the cultivation process were set equal to zero.

- Types of fertilizers: calculated as in the GFLI database, i.e. based on IFAstat consumption data for Denmark over the period 2017-2021

- Multifunctionality (broad beans // straw)
  - economic allocation (99.7% // 0.3%): based on the default prices reported in AFP6.3
  - energy allocation (97.9% // 2.1%): based on the gross caloric value of broad beans from the NorFor’s database (http://feedstuffs.norfor.info/).
    As in AFP6.3, broad beans and straw were modelled with the same gross caloric value (per kg product). This assumption implies that the LCIA results after economic allocation are identical to the LCIA results after mass allocation.
  - mass allocation (97.9% // 2.1%): based on the ratio between removed straw and yields reported in Danmarksstatistik.

- Start material modelled as in AFP6.3

- Drying:
  - An 8% drying is assumed, i.e. from 77% to 85%, via the use of natural gas and electricity
  - The drying model accounts for the loss of mass (which is a refinement compared with the AFP6.3 modelling)
  - The drying process occurs at the farm.

- Direct land use change impacts (on Climate Change) based on LUC Impact Tool (2023) from Blonk Sustainability
  - based on “broad beans” -> “insufficient data”
    The LUC Impact Tool uses the assessment period 2000-2020. Danmarksstatistik (code: HST77) shows that the cultivated area of broad beans in 2020 was 19.2 kha, but there is no data referring to the year 2000. As such, it is not possible to calculate any dLUC from broad beans, as also highlighted by the “insufficient data” in the LUC Impact Tool, and a dLUC = 0 was considered for the calculations.

    Sensitivity analysis: using a conservative approach, and assuming that the cultivated area of broad beans has expanded similarly to the crop “pulses nes” (nes: not elsewhere specified), i.e. ~95% expansion, the LCI of the sensitivity analysis considered a dLUC from Danish broad beans cultivation of 80 kg CO_{2eq} /ha.

- Peat soil oxidation:
  - Given the negligible crop-specific correction factor for Denmark (i.e. between 0.9991 – 1.0024), Danish peat soil oxidation values were modelled by using the country-level average value for all crops (i.e. 987 kg CO_2 /ha and 0 kg CH_4 /ha and 0.616 kg N_2O /ha) as calculated in AFP6.3.

- Modelling of conventional and organic broad beans:
  - The two production systems are modelled using the same methodology.
    The main differences between the two systems are in the use of pesticides (no pesticides in the organic system) and mineral fertilizers (no mineral fertilizers in the organic system), which are reflected in the model.

4 LCIA RESULTS

Table 1, Table 2 and Table 3 summarize the LCIA results, using characterized impacts from ReCiPe 2016 Midpoint (H), for Danish broad beans, produced via both conventional and organic agriculture, expressed after economic allocation, energy allocation and mass allocation, respectively. Additional impact categories are added to comply with the GFLI format: climate change impacts from land use and land use change, and climate change impacts from peat oxidation.

The aggregated and weighted DQR of the three cereals is 1.33.

TABLE 1. LCIA results, expressed as characterized impacts, for broad beans, after **economic allocation** (calculated via ReCiPe 2016 Midpoint (H)). The results of the sensitivity analysis (S.dLUC), where the impacts from dLUC on Climate Change were set equal to 80 kg CO_{2eq} /ha, are also presented. [←: see value to the left]

		1tonne Broad beans conv., dried, at storage {DK}	1tonne Broad beans conv., dried, at storage {DK} [S.dLUC]	1tonne Broad beans org., dried, at storage {DK}	1tonne Broad beans org., dried, at storage {DK} [S.dLUC]
Yields, beans	kg/ha	4162	←	2950	←
DM	-	85.0%	←	85.0%	←
Global warming - Including LUC & Peat	kg CO2 eq	644.2291	665.1874	825.4442	854.9849
Global warming - Excluding LUC & peat	kg CO2 eq	322.4011	←	361.6243	←
Global warming - LUC only	kg CO2 eq	0.1240	20.9583	0.1448	29.5408
Global warming - Peat only	kg CO2 eq	321.7040	←	463.6752	←
Stratospheric ozone depletion	kg CFC11 eq	0.0065	←	0.0074	←
Ionizing radiation	kBq Co-60 eq	7.2506	←	8.1223	←
Ozone formation, Human health	kg NOx eq	0.7512	←	1.0005	←
Fine particulate matter formation	kg PM2.5 eq	0.2648	←	0.2638	←
Ozone formation, Terrestrial ecosystems	kg NOx eq	0.7664	←	1.0210	←
Terrestrial acidification	kg SO2 eq	0.6857	←	0.6102	←
Freshwater eutrophication	kg P eq	0.7224	←	0.0334	←
Marine eutrophication	kg N eq	1.4822	←	1.5140	←
Terrestrial ecotoxicity	kg 1,4-DCB	1566.0018	←	420.1986	←
Freshwater ecotoxicity	kg 1,4-DCB	52.7597	←	6.9429	←
Marine ecotoxicity	kg 1,4-DCB	22.7609	←	9.2308	←
Human carcinogenic toxicity	kg 1,4-DCB	10.5512	←	12.4103	←
Human non-carcinogenic toxicity	kg 1,4-DCB	258.8328	←	137.6539	←
Land use	m2a crop eq	2751.7529	←	3964.4753	←
Mineral resource scarcity	kg Cu eq	2.1464	←	0.7506	←
Fossil resource scarcity	kg oil eq	57.7966	←	62.7501	←
Water consumption	m3	1.2867	←	1.0543	←

TABLE 2. LCIA results, expressed as characterized impacts, for broad beans, after **energy allocation** (calculated via ReCiPe 2016 Midpoint (H)). The results of the sensitivity analysis (S.dLUC), where the impacts from dLUC on Climate Change were set equal to 80 kg CO_{2eq} /ha, are also presented. [←: see value to the left].

		1tonne Broad beans conv., dried, at storage {DK}	1tonne Broad beans conv., dried, at storage {DK} [S.dLUC]	1tonne Broad beans org., dried, at storage {DK}	1tonne Broad beans org., dried, at storage {DK} [S.dLUC]
yields	kg/ha	4162	←	2950	←
DM	-	85.0%	←	85.0%	←
Global warming - Including LUC & Peat	kg CO2 eq	633.3967	653.9732	811.2982	840.3003
Global warming - Excluding LUC & peat	kg CO2 eq	317.4352	←	355.9394	←
Global warming - LUC only	kg CO2 eq	0.1221	20.5765	0.1424	29.0021
Global warming - Peat only	kg CO2 eq	315.8394	←	455.2164	←
Stratospheric ozone depletion	kg CFC11 eq	0.0063	←	0.0072	←
Ionizing radiation	kBq Co-60 eq	7.1452	←	8.0010	←
Ozone formation, Human health	kg NOx eq	0.7382	←	0.9830	←
Fine particulate matter formation	kg PM2.5 eq	0.2603	←	0.2593	←
Ozone formation, Terrestrial ecosystems	kg NOx eq	0.7532	←	1.0031	←
Terrestrial acidification	kg SO2 eq	0.6740	←	0.5999	←
Freshwater eutrophication	kg P eq	0.7093	←	0.0329	←
Marine eutrophication	kg N eq	1.4552	←	1.4864	←
Terrestrial ecotoxicity	kg 1,4-DCB	1538.0381	←	413.1177	←
Freshwater ecotoxicity	kg 1,4-DCB	51.8168	←	6.8352	←
Marine ecotoxicity	kg 1,4-DCB	22.3714	←	9.0878	←
Human carcinogenic toxicity	kg 1,4-DCB	10.3826	←	12.2077	←
Human non-carcinogenic toxicity	kg 1,4-DCB	254.3323	←	135.3609	←
Land use	m2a crop eq	2701.6074	←	3892.1708	←
Mineral resource scarcity	kg Cu eq	2.1085	←	0.7381	←
Fossil resource scarcity	kg oil eq	57.0978	←	61.9604	←
Water consumption	m3	1.2679	←	1.0398	←

TABLE 3. LCIA results, expressed as characterized impacts, for broad beans, after **physical allocation** (calculated via ReCiPe 2016 Midpoint (H)). The results of the sensitivity analysis (S.dLUC), where the impacts from dLUC on Climate Change were set equal to 80 kg CO_{2eq} /ha, are also presented. [←: see value to the left].

		1tonne Broad beans conv., dried, at storage {DK}	1tonne Broad beans conv., dried, at storage {DK} [S.dLUC]	1tonne Broad beans org., dried, at storage {DK}	1tonne Broad beans org., dried, at storage {DK} [S.dLUC]
yields	kg/ha	4162	←	2950	←
DM	-	85.0%	←	85.0%	←
Global warming - Including LUC & Peat	kg CO2 eq	633.3967	653.9732	811.2982	840.3003
Global warming - Excluding LUC & peat	kg CO2 eq	317.4352	←	355.9394	←
Global warming - LUC only	kg CO2 eq	0.1221	20.5765	0.1424	29.0021
Global warming - Peat only	kg CO2 eq	315.8394	←	455.2164	←
Stratospheric ozone depletion	kg CFC11 eq	0.0063	←	0.0072	←
Ionizing radiation	kBq Co-60 eq	7.1452	←	8.0010	←
Ozone formation, Human health	kg NOx eq	0.7382	←	0.9830	←
Fine particulate matter formation	kg PM2.5 eq	0.2603	←	0.2593	←
Ozone formation, Terrestrial ecosystems	kg NOx eq	0.7532	←	1.0031	←
Terrestrial acidification	kg SO2 eq	0.6740	←	0.5999	←
Freshwater eutrophication	kg P eq	0.7093	←	0.0329	←
Marine eutrophication	kg N eq	1.4552	←	1.4864	←
Terrestrial ecotoxicity	kg 1,4-DCB	1538.0381	←	413.1177	←
Freshwater ecotoxicity	kg 1,4-DCB	51.8168	←	6.8352	←
Marine ecotoxicity	kg 1,4-DCB	22.3714	←	9.0878	←
Human carcinogenic toxicity	kg 1,4-DCB	10.3826	←	12.2077	←
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Water consumption	m3	1.2679	←	1.0398	←

5 SUPPLEMENTARY MATERIAL

Restricted access (only to reviewers):

- LCI from OpenLCA (JSON-LD file)
  It is a single product system (with all value chain connections) per each feed ingredient.
  The LCIA results can be calculated as it follows:
    - mass allocation: it can be calculated directly (after the selection of “physical allocation”)
    - economic and energy allocations: they can be calculated following this procedure:
      1. update the revenue cells (mass of the product multiplied by either the price (€/kg) or the energy content (MJ/kg) in the individual companies,
      2. calculate the new allocation factors in the “allocation” tab, using the “calculate from cost/revenue”
      3. close the process,
      4. open the “product system” and calculate the impacts selecting “economic allocation”.
- LCI used in modelling (Microsoft Excel)
- “SM OpenLCA vs SimaPro” (Microsoft Word and Excel)