Report on LCA Analysis

Deliverable 4.1

Dusan Ristic, Sergiy Smetana

DIL, Germany, WP4 Leader

This project has received funding from transnational funding bodies, partners of the H2020 ERA-NETs SUSFOOD2 and CORE Organic Cofund, under the Joint SUSFOOD2/CORE Organic Call 2019. This document reflects only the author's view and the transnational funding bodies are not responsible for any use that may be made of the information it contains.

Content

Introduction

Introduction

The POULTRYNSECT Work Package 4 “**Integrated sustainability assessment**” aims to evaluate the potential changes in the sustainability of chicken meat achieved through Black Soldier Fly live larvae (BSFL) inclusion in the chicken diet.

Within task 4.1, an assessment of environmental impacts associated with all the stages of the production, transformation, and distribution of insect larvae was envisioned. However, due to changes in insect feed applied during the project, as well as the malfunctioning of the device measuring ammonia emissions during insect rearing, it was estimated that the innovativeness of research conducted within task 4.1 would be undermined.

For this reason, as well as due to the fact that milestone 4.1 and deliverable 4.1 refer to the overall life cycle assessment, the scope of research conducted was extended and included the whole chicken meat production chain. The assessment was conducted in a full LCA (Life Cycle Assessment) and the environmental impacts of chicken production were quantified and evaluated.

1. Material and Methods

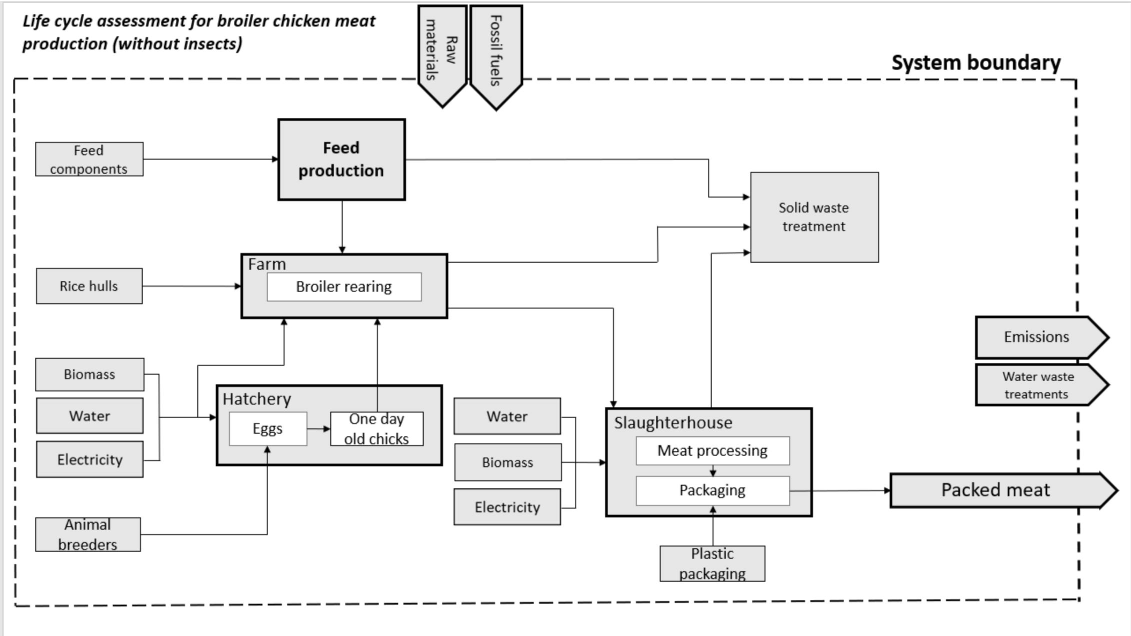
Goal, scope, system boundaries and functional unit

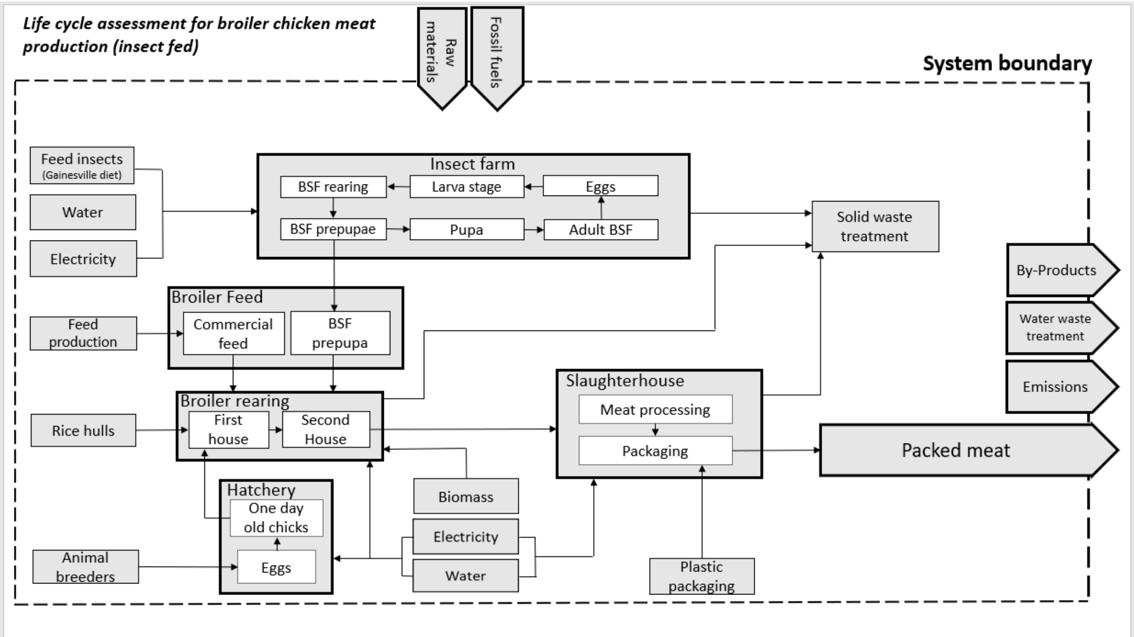
The main goal of the research was to compare the environmental impacts of chicken meat produced conventionally and with the inclusion of 10% of Black Soldier Fly larvae (BSFL) in the diet.

The modular and attributional LCA was developed to assure a structured and quantitative approach. It was predominantly based on the information obtained from the project partners. These include the black soldier fly larvae production, fed on commercial chicken feed, and the first in vivo trial (on breed *Label Naked Neck*) conducted within the project. The data were partly extended by the data from the literature. The underlying data was calculated in the software SimaPro 8.5.2.0 (PŔe Sustainability B.V., Amersfoort, The Netherlands) and followed the standard LCA approach (ISO 14040, 2006 and ISO 14044, 2006). Background data were taken from the ecoinvent 3.4 (ecoinvent, Zurich, Switzerland) and Agri-footprint 4.0 (Blonk Consultants, Gouda, The Netherlands) databases. The methodology of the life cycle impact assessment was IMPACT 2002+. This method represents a practicable realization of a midpoint/damage approach that can show integrated single scores. The functional unit was 1kg of chicken meat. Additionally, 1kg of feed was used as an intermediate functional unit, introduced for improved data management in SimaPro.

This study followed the cradle-to-slaughterhouse gate perspective with further extensions of waste treatments and considered therefore the whole chain of poultry production. The main systems included are feed production, larvae production, hatchery, poultry production, and slaughterhouse. Background processes such as electricity or litter production were included in the system boundaries. All waste streams were treated by relevant waste treatments. The boundaries of the assessment are shown below schematically.

Two different feeding trials were performed on a local Italian chicken breed *Label Naked Neck*. The first group was reared on 90% commercial feed and 10% of insect substitution, which consisted of the *Hermetia illucens* larvae, commonly known as black soldier fly larvae (BSFL). The second group was fully reared on commercial feed and was used as the control group. Within each of the groups, the differences between the sexes were closely followed.





The data used in this study are based on literature sources and experimental data from the chicken-rearing facility of UNITO and the insect-rearing facility of INAGRO. The main literature source for the chicken data was (González-García, et al., 2014) and insect production (Spykman, et al., 2021). As the chicken production took place in Italy, the background data were adapted to Italy. However, this research did not consider transport routes, capital goods, and cleaning agents.

The midpoint and damage categories, as well as single scores, were used in the analysis. Ionizing radiation, the aquatic categories, and ozone layer depletion were determined to be non-resilient environmental categories and were therefore removed from future analysis and results. The evaluated categories included Carcinogens (C), non-carcinogens (NC), respiratory inorganics (RIO), terrestrial ecotoxicity (TE), terrestrial acidification/nitrification (TA), land occupation (LO), global warming potential (GWP), and non-renewable energy (NRE).

Allocation

According to the attributional approach, side streams arising in the value chain are allocated with a relevant environmental impact. This was achieved based on economic values and the mass produced in the corresponding module.

Inventory

The eggs for the chickens were taken to the Hatchery for a period of incubation. After hatching the chickens were transferred to the first rearing facility for 20 days during which they were reared under special conditions. In this facility, 240kg of rice hulls were used, and a light program was set up. For the first day, it was adopted 23 hours of light and 1 hour of darkness, then the timing was reduced to 18 hours of light and 6 hours of darkness in 5 days. Finally, the light was reduced by 3h per day each week, reaching 12h of light and 12h of darkness at 21 days, which is similar to the natural photoperiod. The temperature was 30°C for the first 4 days and then was gradually reduced to finally reach 20°C on day 20, which is similar to the outside temperature. In total, the heating system worked for 2 weeks.

After that, the chickens were transferred to the second building. In this facility, 2400kg of rice hulls were used: 100 kg per pen, accommodating 10 birds per pen. The dimension of each pen was 2.2 x 3.5m. In this building, only natural light was used and there was no heating system.

After those 81 days, the chickens were taken to the slaughterhouse and killed. All the carcasses of the birds slaughtered for experimental purposes were thrown to waste after the samplings were made.

The last live weight was slightly higher in the supplemented birds compared to the controls (2372.72 g vs 2340.60 g).

The diet was composed of two kinds of feeds. The start feed was Pollo Uno and was given to the chickens till day 35. From day 35 till day 81 the chickens were fed by the second feed, Pollo Plus. Pollo Uno was the start-up diet and contained larger amounts of amino acids because the chicks need more proteins in the first days of their lives and bigger amounts of some nutrients, like Calcium and Phosphorus. During that period the chickens were fed a total of 539.6 g of BSF larvae per bird (both females and males). The conventional feed they consumed was organic and the total amount of feed consumed was:

g	Treatment
398500	CM
381495	LM
306280	CF
310295	LF

Pollo plus was used for the remaining days, till day 81. The feed was manufactured by Verzuolo Biomangimi.

The first feed, Pollo Uno (Table 1) is rich in amino acids and has a bigger amount of calcium than Pollo Plus. The biggest amount of proteins comes from soybean meal and soybean oil, meanwhile, alfalfa flour and sunflower panel are rich in fiber.

Table 1 Pollo Uno, Properties

Properties, Pollo Uno
• Crude fiber: 5.85%
• Crude ash: 7.81%
• Crude protein: 22.92%
• Crude fats: 6.19%
• Humidity: 9.56%
Quantities:
• Lysine 11.47g
• Methionine 3.72g
• Phosphorus 7.10g
• Calcium 14.10g
• Sodium 1.98g

Table 2 Pollo Uno, ingredients

Pollo Uno (1-34days)	Quantities	Crude protein	Crude fiber
Maize	430	9.4%	2.5%
Soybean meal	200	55.2%	4.4%
Sunflower panel	75	32.4%	27.9%
Peas	110	23.9%	6%
Corn gluten	80	21.7%	8.3%
Alfalfa flour	15	18.3%	28.6%
Dicalcium phosphate	2	/	/
Calcium carbonate	30	/	/
Soybean oil	20	47%	6.4%
Sodium chloride	3	/	/
Sodium bicarbonate	1	/	/
Potato starch	34	0.8%	0.2%

The second feed, Pollo Plus Table 3 has a lower amino acid quantity, and just as in Pollo Uno, the proteins come mainly from soybean meal and soybean oil, meanwhile, the primary source of fiber is alfalfa flour and sunflower panel.

Table 3 Pollo Plus Properties

Percentages (Pollo Plus)
• Crude fiber: 6.26%
• Crude ash: 6.22%
• Crude protein: 20.52%
• Crude fats: 5.12%
• Humidity: 9.90%
Quantities
• Lysine 9.16g
• Methionine 3.60g
• Phosphorus 5.36g
• Calcium 10.65g
• Sodium 1.71g

Table 4 Pollo Plus, ingredients

Pollo Plus (1-34days)	Quantities	Crude protein	Crude fiber
Maize	509	9.4%	2.5%
Soybean meal	150	55.2%	4.4%
Sunflower panel	80	32.4%	27.9%
Peas	130	23.9%	6%
Corn gluten	80	21.7%	8.3%
Alfalfa flour	25	18.3%	28.6%
Dicalcium phosphate	2	/	/
Calcium carbonate	20	/	/
Sodium chloride	3	/	/
Sodium bicarbonate	1	/	/

The data for the Inputs and Outputs for feed production was taken from (González-García, et al., 2014). The functional unit for feed production is 1kg of feed.

2. Results & discussion

Feed requirements

To produce 1kg of chicken meat from the male BSF-fed chickens, roughly 3798g of feed was required, along with 316.9g of larvae. To produce 1kg of chicken meat from the female BSF-fed group the same amount of BSF larvae was used, but coupled with 3089g of feed, a significantly smaller amount. The same pattern was observed with control, commercially fed chicken. The male commercial-fed chickens consumed 4022.7g of feed per 1kg of chicken meat produced, while female commercial-fed chickens consumed 3091.8g of commercial feed per 1kg of chicken meat produced. Interestingly, female commercial-fed chickens consumed only about 3g of commercial feed more than the BSFL-fed ones, apparently not compensating for the insects they didn't receive. Also, the difference between the feed consumption of the males and females is due to the sex difference and results in the end weight of the males being higher than that of the females.

Life cycle assessment

The endpoint results (Figures 1 and 2) show that there is no significant difference in the environmental impact of chicken meat introduced by the inclusion of 10% of BSFL into the chicken diet. The observed differences can be attributed to the difference between the two sexes rather than to the inclusion of insects into the diet.

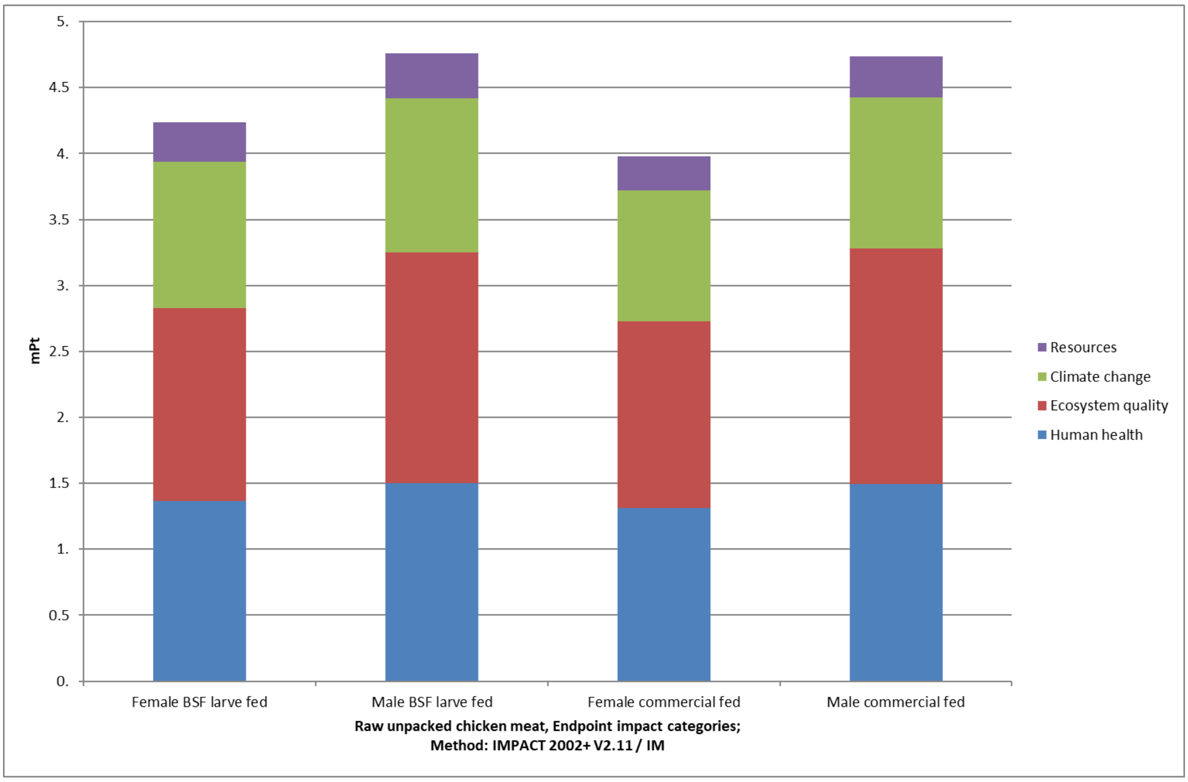


Figure 1 Aggregated endpoint impact categories of chicken meats

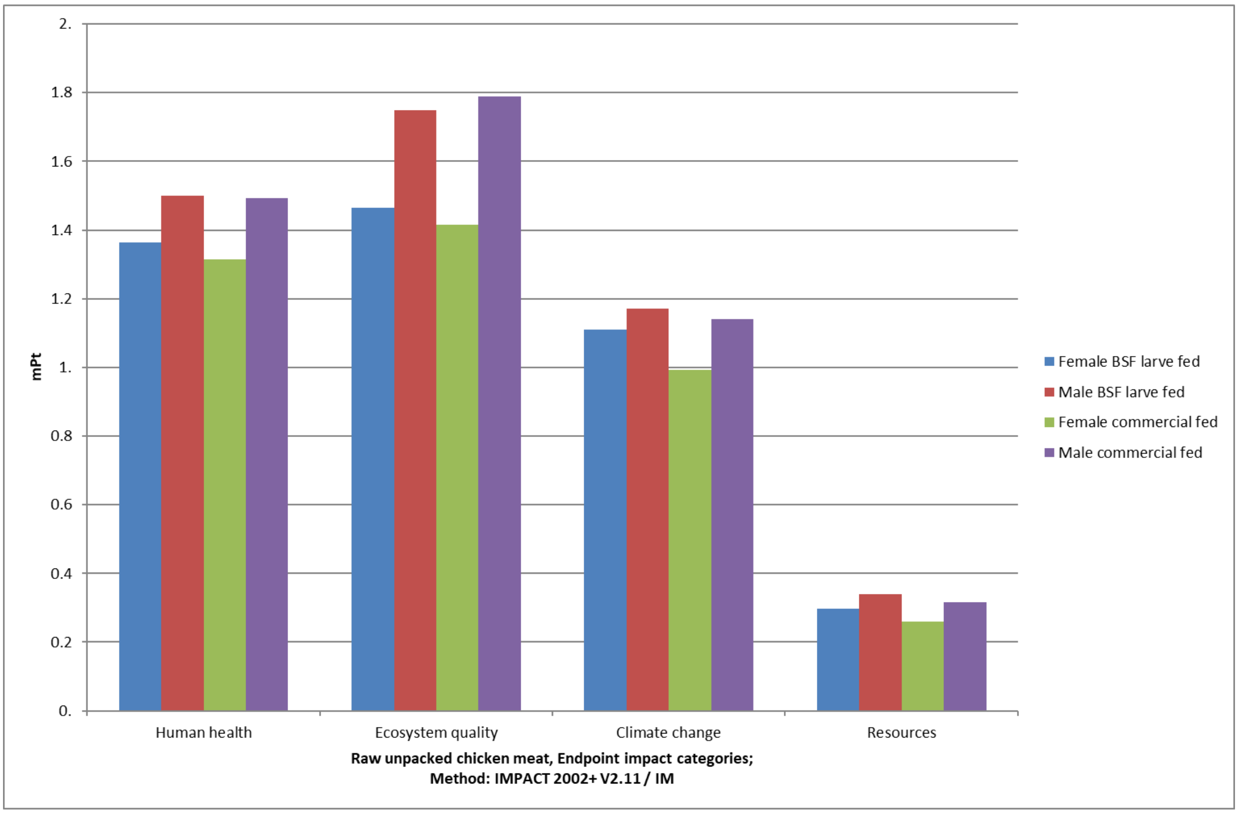


Figure 2 Endpoint impact categories, chicken meats

The midpoint impact assessment results can be seen in Table 5 and Figure 3. All the chicken groups for the whole production process returned similar results. Global warming potential (GWP), Land occupation (LO), and Respiratory inorganics (RIO) achieved the highest values.

Table 5 Midpoint category results

Midpoint category	Female BSF larvae fed	Male BSF larvae fed	Female commercial fed	Male commercial fed
Carcinogens	0.0632	0.067	0.06	0.065
Non-carcinogens	0.3604	0.393	0.3663	0.4088
Respiratory inorganics	0.938	1.0382	0.8856	1.0171
Ionizing radiation	0.001	0.0012	0.0009	0.001
Ozone layer depletion	3.68E-05	4.16E-05	3.31E-05	3.95E-05
Respiratory organics	0.0008	0.0009	0.0007	0.0009
Aquatic ecotoxicity	0.004	0.0046	0.004	0.0048
Terrestrial ecotoxicity	0.4228	0.5233	0.4483	0.5804
Terrestrial acid/nutri	0.0448	0.0482	0.0436	0.048
Land occupation	0.9924	1.1725	0.9187	1.1553
Aquatic acidification	0	0	0	0
Aquatic eutrophication	0	0	0	0
Global warming	1.1095	1.1718	0.9924	1.1417
Non-renewable energy	0.2967	0.3389	0.2586	0.314
Mineral extraction	0.001	0.0013	0.001	0.0012

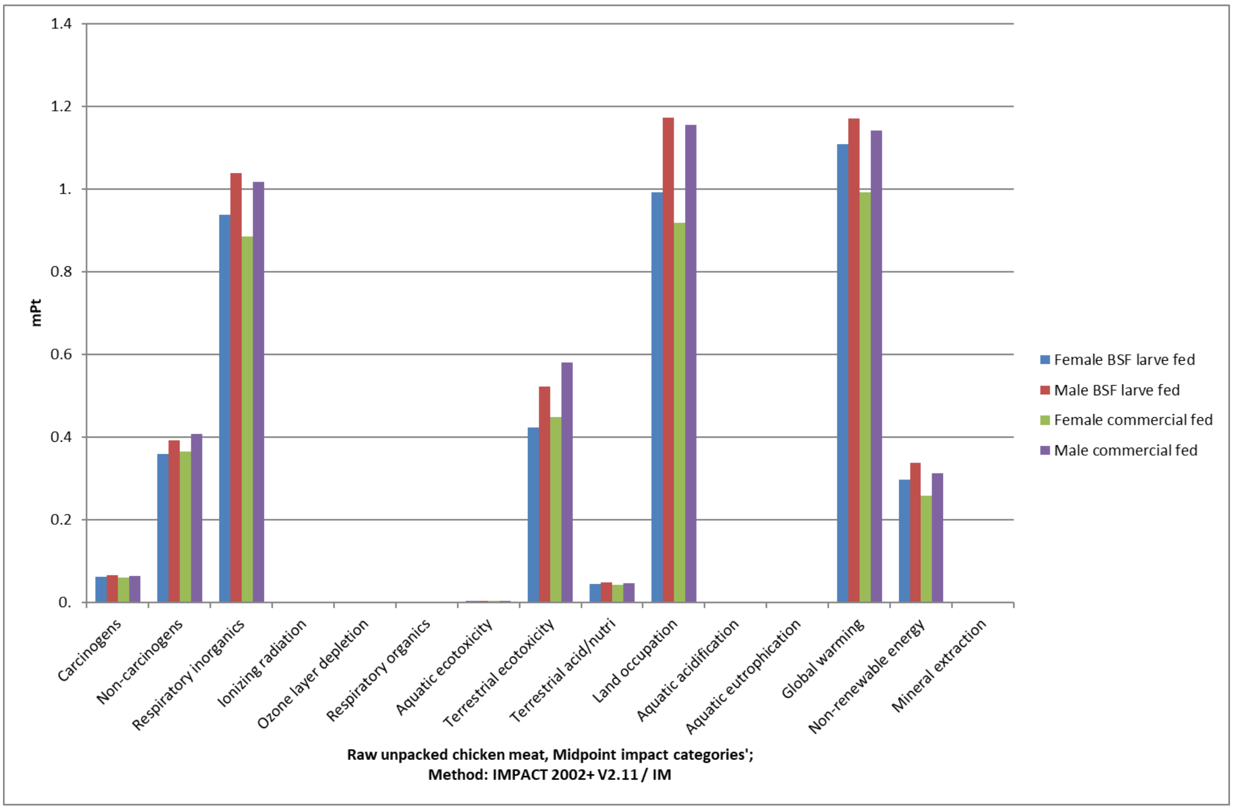


Figure 3 Midpoint impact categories, chicken meats

3. Conclusion

Based on the experimental data received from project partners for the first batch of Label Naked Neck broilers partially fed on Black Soldier Fly Larvae, it can be concluded that the inclusion of 10% of larvae into chicken feed did not lead to statistically significant environmental gains. Better results might be expected if insect feed would be adjusted to overproduced fruits and vegetables, and if the portion of BSFL in broilers' diet would be increased.

References

González-García, S., Gomez-Fernández, Z., Dias, A.C., Feijoo, G., Moreira, M.T., Arroja, L., 2014. Life Cycle Assessment of broiler chicken production: A Portuguese case study. J. Clean. Prod. 74, 125–134. https://doi.org/10.1016/j.jclepro.2014.03.067

Spykman, R., Hossaini, S.M., Peguero, D.A., Green, A., Heinz, V., Smetana, S., 2021. A modular environmental and economic assessment applied to the production of Hermetia illucens larvae as a protein source for food and feed. Int. J. Life Cycle Assess. 26, 1959–1976. https://doi.org/10.1007/s11367-021-01986-y

Heines, W., Ristic, D., Rosenberger, S., Coudron, C., Gai, F., Schiavone, A., Smetana, S. (2023) Eggs or meat? Environmental impact and efficiency assessment of chicken protein production with potential of Hermetia illucens use in feed. Resources, Conservation & Recycling Advances 16 (2022): 200121. https://doi.org/10.1016/j.rcradv.2022.200121

POULTRYNSECT

This project has received funding from transnational funding bodies, partners of the H2020 ERA-NETs SUSFOOD2 and CORE Organic Cofund, under the Joint SUSFOOD2/CORE Organic Call 2019. This document reflects only the author's view and the transnational funding bodies are not responsible for any use that may be made of the information it contains.