Life cycle assessment – Cultured meat

Introduction

This study deals with a Life Cycle Impact Assessment (LCIA) of Cultured Meat production under different scenarios. These scenarios pertain to the sources of proteins derived from animal waste products. Additionally, extraction of glucose from wheat was also modelled into the scenarios for additional insights. Comparisons were made with existing publications, in particular to the baseline scenario (CMB) in a published paper that was chosen as a reference (Tuomisto et al., 2022). The study design and LCA parameters are explained as below:

Goal and scope

The purpose of this LCA was to assess the environmental impacts of cultured meat produced using bioreactors located in the UK in the year 2024. A functional unit (FU) of 1 kg of meat produced was used for the analysis. The system boundary has been given below consisting of cradle-to-gate processes from raw material extraction up to factory gate. This can be seen in Figure 1 which shows also that inputs for building construction and equipment manufacturing were not considered in this LCA. Figure 1 has been taken from (Tuomisto et al., 2022) and also displays waste management as part of the system boundary which involved water sterilisation. The use of sodium hydroxide and some electricity for cleaning bioreactor was also modelled in the reference paper (Tuomisto et al., 2022). However, this study did not include these inputs.

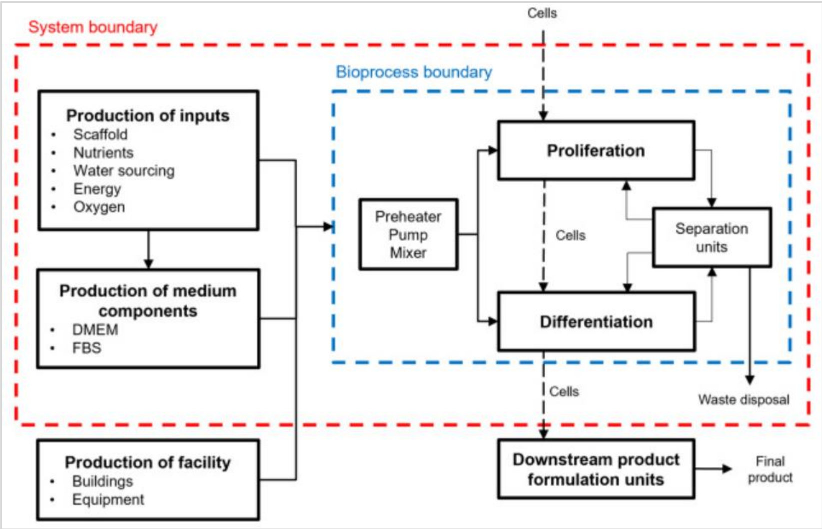

Figure 1: System boundary of cultured meat production (Tuomisto et al., 2022).

The LCA was performed using SimaPro software and the impacts were based on ReCiPe Midpoint 2016 (H) methodology. It is important to note that the production of cultured meat also leads to the production of lactate, which can be used for producing lactic acid. Similarly, a minute quantity of ammonia is also produced. For this analysis, 100% of the impacts will be allocated to the cultured meat which can then be compared against scenarios where allocation takes place against certain criteria (economic allocation vs mass allocation (dry mass, wet mass), substitution, etc). scenario analysis will be based on the use of valorised proteins as explained above. LCI data for these sources was obtained from relevant scientific articles. Specifically, LCI for rapeseed and horn/hoof derived proteins was obtained from literature (Colantoni et al., 2017) and that for blood protein was obtained from another paper (Bier et al., 2012). This is also one of the limitations of this study.

Results

The results have been presented using the impact categories of global warning potential (GWP), water consumption (WC), terrestrial acidification potential (TAP), ozone formation potential (OFP), land use (LU), freshwater eutrophication potential (FEP), fossil resource scarcity (FRS) and fine particulate matter formation (FPM). Table 1 below presents these results. Table 1 shows that the impacts are relatively lower than those in the reference study (Tuomisto et al., 2022). Using proteins from waste sources can reduce the impacts further with the largest impacts coming from the use of bovine blood source followed by horn/hoof and rapeseed sources, in that order. The results from the original study have also been provided in the form of mean values and standard deviations. The values calculated using the same data are within the Standard deviation for almost all impacts. Differences can be attributed to the exclusion of inputs for bioreactor cleaning, possible variation in data for background processes, different software (Silva et al., 2019), etc .

Table 1 – Results from comparative LCA of cultured meat sources.

Impact category *	Abb	Unit	Tuomisto original**	Tuomisto	Baseline	Protein		
						Bovine	Horn/hoof	Rapeseed
Global warming	GWP	kg CO2 eq	2.51E+01 (4.60E+00)	2.21E+01	1.61E+01	1.47E+01	1.34E+01	1.33E+01
Fine particulate matter formation	FPM	kg PM2.5 eq	3.90E-2 (8.00E-03)	3.55E-02	2.43E-02	2.16E-02	2.07E-02	2.03E-02
Terrestrial acidification	TAP	kg SO2 eq	1.20E-01 (2.00E-02)	1.13E-01	7.39E-02	6.38E-02	6.14E-02	6.08E-02
Freshwater eutrophication	FEP	kg P eq	1.00E-02 (0.00)	7.91E-03	5.97E-03	5.33E-03	5.14E-03	5.08E-03
Land use	LUP	m2a crop eq	6.89E+00 (1.33E+00)	4.07E+00	2.80E+00	2.42E+00	2.25E+00	2.25E+00
Fossil resource scarcity	FRS	kg oil eq	7.60E+00 (1.33E+00)	6.45E+00	5.41E+00	5.09E+00	4.64E+00	4.61E+00
Water consumption	WC	m3	5.40E-01 (4.30E-01)	3.57E-01	1.94E-01	1.63E-01	1.63E-01	1.58E-01

* All impacts of the process were allocated to cultured meat, lactate and ammonia were regarded as by-products without any allocation. **Values in parentheses represent standard deviations.

Figure 2 presents the results for the contributions of key inputs to the GWP. It can be seen that DMEM was the single highest contributor to the impact. The second highest impact came from the use of energy for the data in the reference study (Tuomisto et al., 2022) and Glucose/Glutamine use in the present study. The relatively lower impacts in the present study were primarily due to a relatively lower quantity of amino acids (down 34.4%) and energy consumed by bioreactor (down 25.2%).

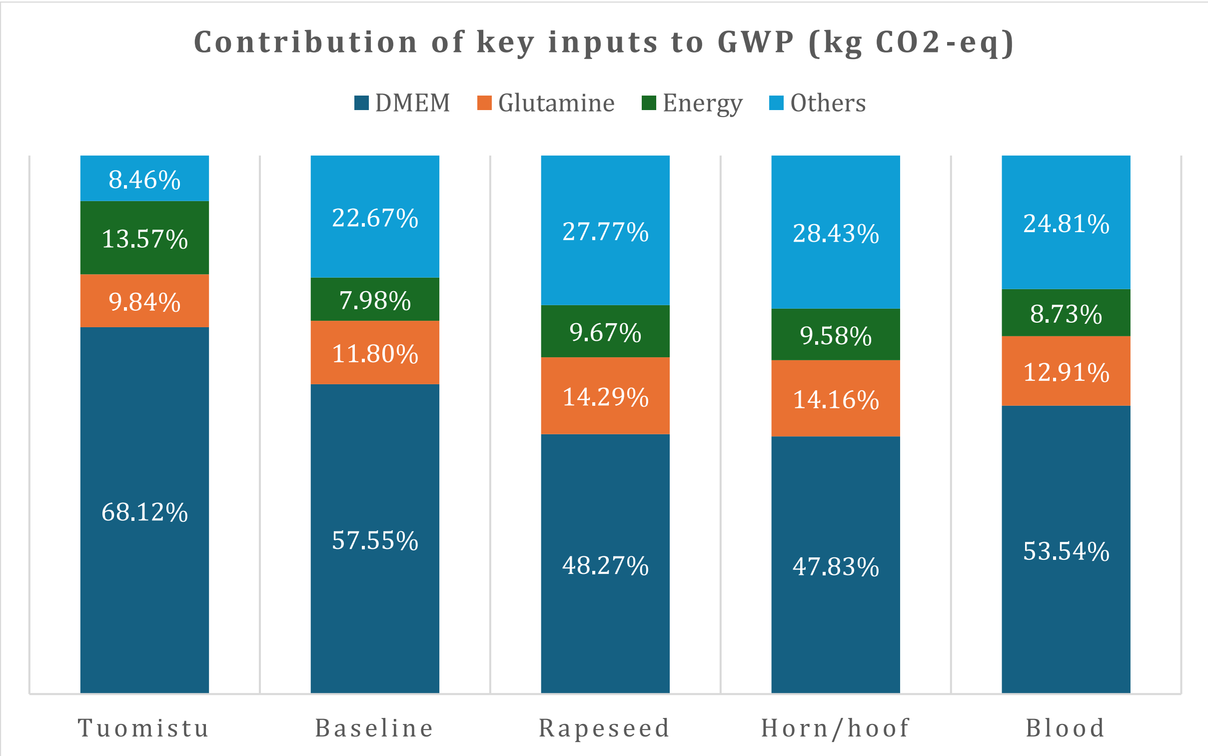

Fig 2 – Results displaying contribution of key inputs to GWP.

Figures 3 and 4 present a comparison between the DMEM sources and proteins against the above-mentioned impact categories respectively. Both of these figures reflect the same order as presented in Table 1. Figure 3 highlights this even further by focusing only on the protein sources. It can be seen that using bovine blood as a protein source has a much greater environmental impact than that from the other 2 sources. It must be highlighted here that the LCI for the protein sources was obtained from published articles and wasn't derived from experimental work. As such, these results should be interpreted with caution.

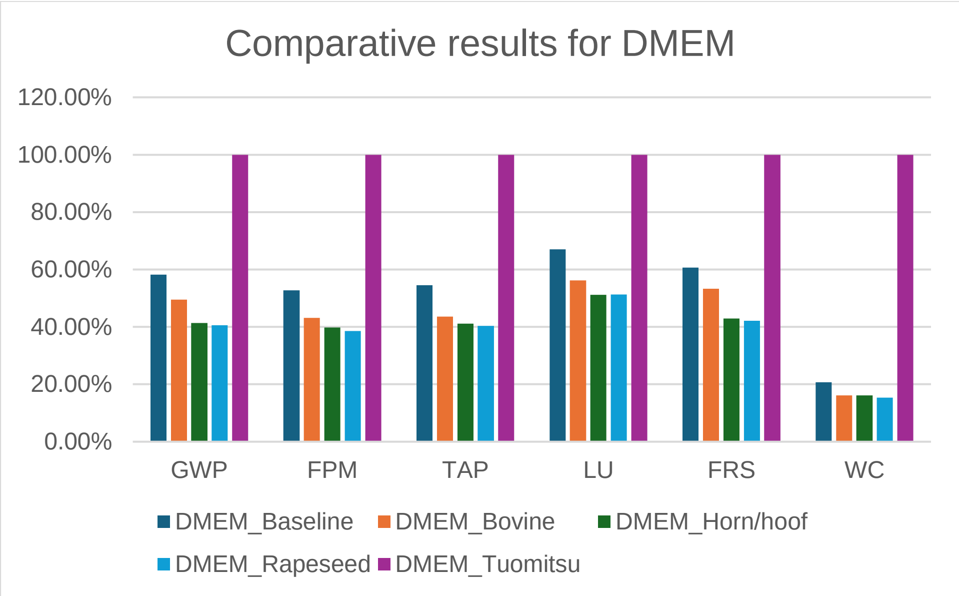

Fig 3 – Results for comparative LCA of DMEMs.

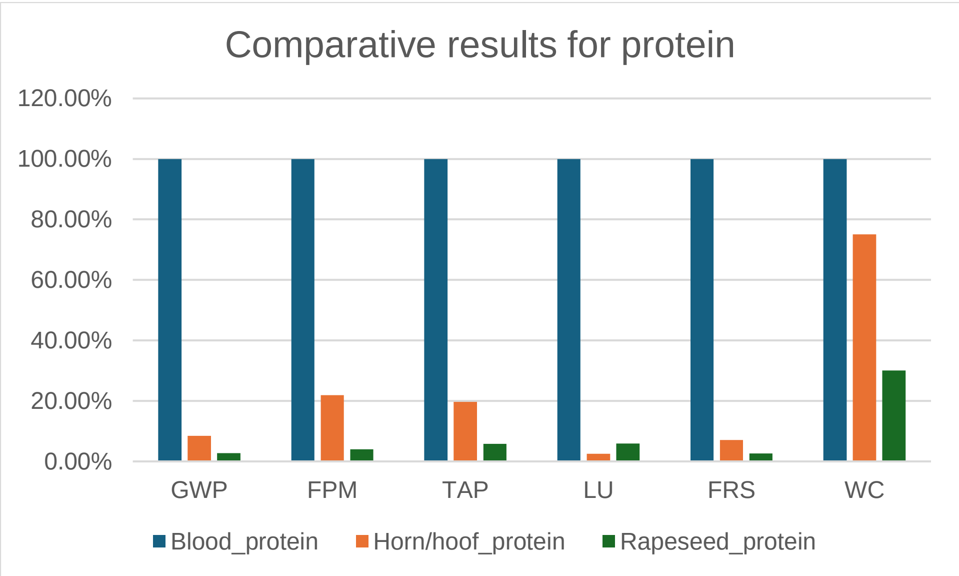

Fig4 – Results for comparative LCA of proteins.

Closer inspection reveals that DMEMs are the greatest (>50%) source of impacts in most categories in all scenarios followed by Glutamine and energy use respectively. DMEMs can be made more sustainable by using proteins valorised from wastes as explained above.

Similarly, renewable sources of electricity can reduce the overall burdens from energy use in the long run. For glucose, a scenario involving wheat source was compared with default values from Ecoinvent database (Wernet et al., 2016). The LCI for glucose from wheat was obtained from (Salim et al., 2019). The results have been presented in Figure 5 which shows, relatively higher impacts from conventional glucose in almost all categories. Once again, this result should be interpreted with caution as the underlying data was obtained from secondary sources.

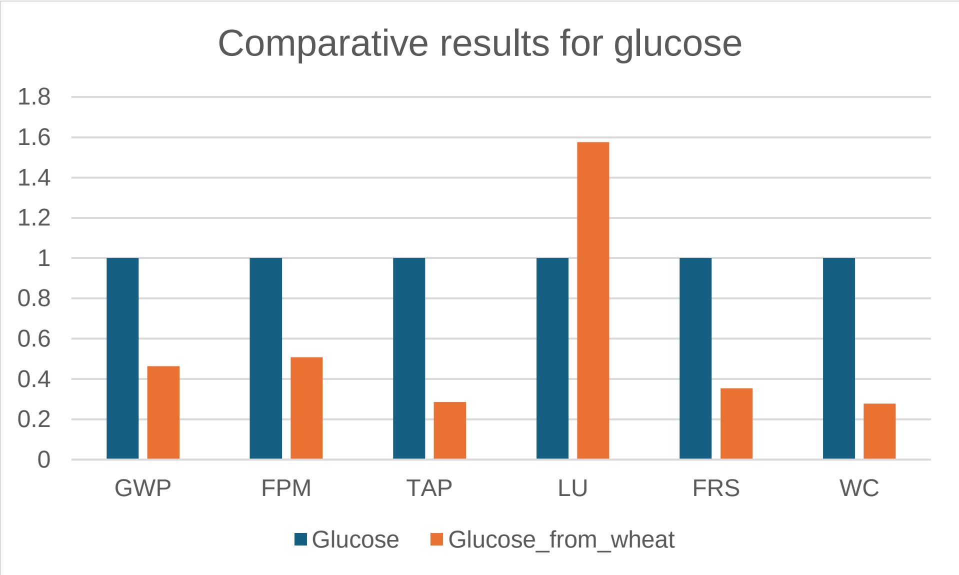

Fig 5 – Results for comparative LCA of glucose sources.

Limitations

The data used in the present study came from different sources some of which were not experimental. The data for valorised proteins was obtained from published sources and significant gaps in the LCI inventory are possible. Similarly, the quality of the amino acids from the valorised sources may or may not be directly comparable to that produced for cultured meat in a conventional setting. Similarly, comparison between glucose sources should ideally be carried out when they have the same source of data. Otherwise, significant gaps in the results can exist. Similarly, the data for the non-valorised inputs was provided by other members of the team and as such the assumptions behind those numbers remain unknown.

In order to address the uncertainties associated with this study, future work can use a wider literature review to identify data for valorised proteins. Better still, experimental work could yield a reliable inventory for these sources. The impact of energy transition or variation on the overall results can also be accounted for. Perhaps more importantly, comparisons with conventional beef production should also be made based on primary data collection.

References

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