ADDENDUM TO:

IMPOSSIBLE FOODS SAUSAGE MADE FROM PLANTS LCA

CLIENT:

IMPOSSIBLE™

Final version

SEPTEMBER 29, 2021

WSP CANADA

wsp.com/ca

ISO-CONFORMANT LIFE CYCLE ASSESSMENT REPORT

Addendum to "Impossible Sausage Made from Plants Final Report LCA" which is published here.

Client:
Impossible Foods Inc. ("Impossible Foods")
Redwood City, California, CA

Client Contact:
Arjun Pillai Hausner, Senior Analyst, Impact Strategy
arjun.hausner@impossiblefoods.com

Study Practitioner:
WSP Canada Inc.
Colin Powell, PhD
Colin.powell@wsp.com

DISCLAIMER

WSP Canada ("WSP") prepared this report solely for the use of the intended recipient, Impossible Foods (IF)), in accordance with the professional services agreement between the parties. In the event a contract has not been executed, the parties agree that the WSP General Terms for Consultant shall govern their business relationship which was provided to you prior to the preparation of this report.

The report is intended to be used in its entirety. No excerpts may be taken to be representative of the findings in the assessment.

The conclusions presented in this report are based on work performed by trained, professional and technical staff, in accordance with their reasonable interpretation of current and accepted engineering and scientific practices at the time the work was performed.

The content and opinions contained in the present report are based on the observations and/or information available to WSP at the time of preparation, using investigation techniques and engineering analysis methods consistent with those ordinarily exercised by WSP and other engineering/scientific practitioners working under similar conditions, and subject to the same time, financial and physical constraints applicable to this project.

WSP disclaims any obligation to update this report if, after the date of this report, any conditions appear to differ significantly from those presented in this report; however, WSP reserves the right to amend or supplement this report based on additional information, documentation or evidence.

WSP makes no other representations whatsoever concerning the legal significance of its findings.

The intended recipient is solely responsible for the disclosure of any information contained in this report. If a third party makes use of, relies on, or makes decisions in accordance with this report, said third party is solely responsible for such use, reliance or decisions. WSP does not accept responsibility for damages, if any, suffered by any third party as a result of decisions made or actions taken by said third party based on this report.

WSP has provided services to the intended recipient in accordance with the professional services agreement between the parties and in a manner consistent with that degree of care, skill and diligence normally provided by members of the same profession performing the same or comparable services in respect of projects of a similar nature in similar circumstances. It is understood and agreed by WSP and the recipient of this report that WSP provides no warranty, express or implied, of any kind. Without limiting the generality of the foregoing, it is agreed and understood by WSP and the recipient of this report that WSP makes no representation or warranty whatsoever as to the sufficiency of its scope of work for the purpose sought by the recipient of this report.

In preparing this report, WSP has relied in good faith on information provided by others, as noted in the report. WSP has reasonably assumed that the information provided is correct and WSP is not responsible for the accuracy or completeness of such information.

WSP disclaims any responsibility for consequential financial effects on transactions or property values, or requirements for follow-up actions /or costs.

The original of this digital file will be kept by WSP for a period of not less than 10 years. As the digital file transmitted to the intended recipient is no longer under the control of WSP, its integrity cannot be assured. As such, WSP does not guarantee any modifications made to this digital file subsequent to its transmission to the intended recipient. This limitations statement is considered an integral part of this report.

Contents

TABLES

FIGURES

EXECUTIVE SUMMARY

Impossible Foods Inc. (Impossible Foods) has developed a new plant-based meat alternative (PBMA), Impossible Ground Pork Made from Plants (IGP), that aims to mimic the flavour and texture of ground pork sausage (PS). The company has undertaken work to calculate four specific life cycle environmental indicators of the different versions of the product: global warming potential, aquatic eutrophication, land occupation and water depletion. In this report, which is an addendum to a previous report (Impossible Foods, 2020), four life cycle environmental indicators of an IGP product, manufactured in the United States (US), with one scenario delivered to the US (IGP – US) and one scenario delivered to China (IGP – CN), are compared against a functionally equivalent PS produced in the US (PS – US) and produced in China (PS – CN), and delivered to their respective domestic markets.

Boundary and scope

The type of inventory is cradle-to-gate of retailer (defined as the initial purchaser of finished product, whether a distributor, foodservice operator, or traditional retailer), prior to purchase by an end consumer; the retail, use and end-of-life stages are excluded from the boundary because they are assumed to be identical for the respective comparative scenarios (i.e., the IGP has similar cooking time, specific heating capacity, shelf-life and distribution systems to the PS).

The four environmental indicators for all scenarios are considered on a per kilogram (kg) of delivered final product basis. IMPACT 2002+ v2.12 was used to quantify global warming potential, aquatic eutrophication and land occupation; ReCiPe Midpoint (H) v1.12/World Recipe H was used to quantify water depletion. These four environmental indicators were quantified using primary data from Impossible Foods manufacturing facilities and secondary data from literature, industry sources and commercial databases. Only the results for the four environmental indicators were quantified because these are the key environmental areas of concern for Impossible Foods.

Results

In general, the four environmental indicators of the IGP are lower than the PS. A brief summary of the range of results is provided below:

- 1 kg of IGP shows a global warming result between 5.2 kg CO_2e and 5.6 kg CO_2e (73% and 77%) lower than 1 kg of PS, with the higher result for the IGP when it is distributed in China.
- 1 kg of IGP shows an aquatic eutrophication result between 0.76 g PO_4^{3-}eq and 0.77 g PO_4^{3-}eq (52%) less than 1 kg of PS, as it avoids some crop fertilizer and manure application emissions present in pig production.
- 1 kg of IGP shows a land occupation result between 3.90 m^2·org. arable·year and 8.98 m^2·org. arable·year (66% to 82%) less than 1 kg of PS. The largest contribution for the IGP is the production of sunflower oil, which has a much lower yield than other crops in the ingredients.
- 1 kg of IGP shows a water depletion result between 0.44 m^3 and 0.57 m^3 (81% to 85%) less than 1 kg of PS. This is due to the much lower demand for agricultural irrigation for the IGP ingredients than for the pig feed ingredients and high-water withdrawal (and low water returned) for the pig production and slaughterhouse stages.

More detailed results are provided in the report. The IGP studied in this work generally has lower environmental indicators than the two products previously studied (Impossible Sausage Made from Plants 1 and 2 (IS1 and 2)) in Impossible Foods (2020) because of a lower amount of heme, sunflower oil, and coconut oil in the recipe. Comparatively, the IGP shows a benefit to the PS with respect to the four potential environmental indicators, as expected.

In summary, the study has found that there are clear potential environmental benefits in the environmental indicators of concern discussed in this study, to using IGP examined in this work compared to PS.

Assessment Summary

Life Cycle Assessment (LCA)	
Life Cycle Assessment over select potential environmental indicators for Impossible Foods	
Parameter	**Description**
Company Name and Contact Information	*Study Commissioner:* Impossible Foods Redwood City, California, USA *Client Contact:* Arjun Pillai Hausner arjun.hausner@impossiblefoods.com *Study Practitioners:* WSP Canada Inc. Colin Powell Colin.powell@wsp.com
Standards Used	ISO 14044:2006 Environmental management – Life cycle assessment – Requirements and guidelines
Product Name	The product under study is identified as Impossible Sausage 3 (IGP) to follow the products studied in a previous LCA.
Product Description	The IGP product is an uncooked, frozen plant-based meat alternative (PBMA) meant to mimic ground pork and to be used in place of pork as a plant-based substitute.
Functional Unit (study basis)	The function of the product is food for human consumption. The functional unit is one kilogram (kg) of product at the retailer.
Temporal Boundary	Data from Impossible Foods are up to date and relevant for the current year. Secondary data from Ecoinvent v3.7 databases have a validity range between 2009 and 2019. The time period in which the results should be considered valid is five years from publication date of this study.
Country/Region of Product Consumption	The IGP is produced in Oakland, California, US and distributed to the US and China. The pork studied in this work comparatively is produced in the US and China, and distributed in the domestic markets, respectively.
Version and Date of Issue	Final version – September 29, 2021.

Glossary of Terms

CA: California

GaBi®: Life cycle assessment software program

GWP: Global Warming Potential

IL: Illinois

IGP: Impossible Ground Pork Made From Plants

IS: Impossible Sausage Made from Plants

IS1 and 2: Specific recipes and cooking formulations of the IS

ISO: International Organization for Standardization

LCI: Life Cycle Inventory

LCIA: Life Cycle Impact Assessment

PBMA: Plant-based meat alternative

PS: Ground pork sausage functionally equivalent to IGP

US: United States

1 CONTEXT

In October 2020, Impossible Foods Inc. (Impossible Foods) released the life cycle assessment (LCA) for their Impossible Sausage Made From Plants (IS) product (Impossible Foods, 2020). The study, released October 10, 2020[1], reviewed four different scenarios, comparing different compositions of the IS products with different destinations (United States (US) and China) against typical ground pork sausage (PS) products with different origins and destinations (US and China).

A brief summary of the results of that previous LCA, noting that IS1 and IS2 are not perfectly comparable as one is cooked and one is uncooked, and have different functional units, is provided below (Impossible Foods, 2020):

- 1 kg of IS shows a global warming result between 4.2 kg CO_2e and 5.3 kg CO_2e (58% and 73%) lower than 1 kg of PS patty, with the higher result for the IS when it is distributed in China.
- 1 kg of IS shows an aquatic eutrophication result between 0.77 g PO_4^{3-}eq and 0.88 g PO_4^{3-}eq (52% and 60%) less than 1 kg of PS patty, as it avoids some crop fertilizer and manure application emissions present in pig production.
- 1 kg of IS shows a land occupation result between 2.45 m^2·org.arable·year and 7.79 m^2·org.arable·year (41% to 71%) less than 1 kg of PS patty. The largest contribution for the IS is the production of sunflower oil, which has a much lower yield than other crops in the ingredients.
- 1 kg of IS shows a water depletion result between 0.44 m^3 and 0.56 m^3 (79% to 83%) less than 1 kg of PS patty. This is due to the much lower demand for agricultural irrigation for the IS ingredients than for the pig feed ingredients and high-water withdrawal (and low-water returned) for the pig production and slaughterhouse stages.

That study was critically reviewed as per ISO 14044 (ISO, 2006).

The purpose of this addendum is to provide the results of an additional scenario comparing a new IS product (IGP), which is expected to be introduced by Impossible Foods in 2021, against its functionally equivalent PS product (PS).

It is noted that this document was not critically reviewed even though a comparative assertion is made. The justification to not bring this addendum before a Critical Review Panel was made because this addendum only represents small incremental changes from the original study with only a recipe change to IGP from IS1 and no new PS product studied. The only difference in IGP from IS1 is an incremental change in recipe and because the processes used in IS1 are identical to that of IGP (just the amounts have changed), then there is no marginal ISO-related topics to discuss beyond what was already reviewed in the previous LCA's Critical Review.

[1] The Impossible Sausage Made from Plants LCA is available here as of September 29, 2021.

2 GOAL OF THE STUDY

Impossible Foods commissioned WSP Canada Inc. ("WSP") to develop an addendum to Impossible Foods' previous LCA for Impossible Sausage Made From Plants (Impossible Foods, 2020). The goal of this addendum is to compare the four potential environmental impact indicators (global warming, aquatic eutrophication, land occupation and water depletion) of one additional Impossible Foods product, Impossible Ground Pork Made From Plants, made in the US and distributed to the US and China, against the ground pork sausage functional equivalent produced in the US and China. As per the previous LCA, no additional metrics were examined and justification for this is provided in that LCA (Impossible Foods, 2020).

This study analyzes IGP only and the results cannot necessarily be considered replicable for any other Impossible Foods product.

2.1 REASONS FOR CARRYING OUT THE STUDY

This study was conducted to inform internal decision-making and to provide information to the public who are interested in the potential environmental impacts of Impossible Foods' products. These four potential environmental indicators are of interest to Impossible Foods and their stakeholders.

The company commissioned this study to determine the absolute values of four potential environmental indicators from the life cycle of their company's IGP product and compare those values against meat-based benchmarks. Therefore, the results of this study include absolute and comparative values that are intended to be communicated externally.

2.2 INTENDED APPLICATIONS

This project report is intended to support Impossible Foods in quantifying those four particular environmental indicators associated with IGP ingredients, production, and in distribution and in supporting the comparative assertions of those four particular environmental indicators associated with the IS products studied here against the functionally equivalent PS, intended to be disclosed to the public.

2.3 TARGET AUDIENCE

Specific audiences may include the company's employees, business partners, customers, and the general public. The study results are prepared for both Impossible Foods' internal use and to be communicated externally in conformance with ISO 14067 (ISO, 2018).

2.4 COMPARATIVE ASSERTION FOR PUBLIC DISCLOSURE

This LCA is intended to be compliant with the requirements of ISO 14044 (ISO, 2006), which governs the requirements for public product-to-product comparisons for LCAs. A comparative assertion is intended to be made with the products described in this report but it was deemed not subject to critical review as the previous work (Impossible Foods, 2020) with not dissimilar inputs and results was already subjected to critical review. We do not believe critical review is necessary for this addendum as it only represents small incremental changes from the original study with only a recipe change to IGP from IS1 and no new PS product studied. The only difference in IGP

from IS1 is an incremental change in recipe and because the processes used in IS1 are identical to that of IGP (just the amounts have changed), then there is no marginal ISO-related topics to discuss beyond what was already reviewed in the previous LCA's Critical Review.

3 SCOPE OF THE STUDY

3.1 FUNCTION

The functions of the IGP and PS are to provide food for consumers to eat.

3.2 FUNCTIONAL UNIT

In order to maintain functional equivalence, the functional unit for the IGP and PS products compared is 1 kg of food at a retailer (uncooked and frozen).

While it is acknowledged that there is not a single measurement on which to set a functional basis for food consumed due to the multiple reasons people eat food (i.e., for nutrition, to reduce or mitigate hunger, social gathering, etc.), the IGP was designed to be nutritionally similar to ground pork. Table 1 provides the nutritional data for the IGP and PS with a comparable protein amount per mass.

Table 1 – Nutritional data for IGP and PS

Nutrient	Units	IGP – 100 g (provided by Impossible Foods)	PS – 100 g (USDA, 2019)*
Calories	kcal	197.05	310
Fat	g	11.285	28
Saturated fat	g	6.09	9
Trans fat	g	0	0
Cholesterol	mg	0	76
Sodium	mg	256.5	70
Carbs	g	8.25	0
Total Dietary Fiber	g	3.18	0
Total Sugars	g	0.59	0
Added Sugars	g	0.59	0
Protein	g	15.31	15

*Nutritional information provided for 72/28 lean at ground pork, raw (USDA, 2019)

The products are compared in this LCA on a per-mass basis, as was done in the original LCA. Justification for this choice and a sensitivity analysis against that choice is provided in the previous LCA (Impossible Foods, 2020).

3.3 DESCRIPTIONS OF THE SYSTEMS

As noted above, the IGP is compared against a functionally equivalent ground pork product, labelled PS. The systems studied are discussed in this section.

3.3.1 IMPOSSIBLE SAUSAGE MADE FROM PLANTS – IGP

There is one variety of the IGP under study in this LCA. It is a plant-based meat alternative (PBMA) that is meant to mimic raw pork, has no additional flavouring, and is delivered uncooked and frozen to a retailer.

The boundary of the system studied includes all activities necessary to produce the IGP from "cradle to the gate of the retail/wholesale distributor's truck." Retail, use and end-of-life stages are excluded from the study as these do not differ significantly between the IGP and the reference PS products. Overhead services (e.g., lighting and heating of buildings on site) are considered a non-attributable process (i.e., processes that are not directly connected to the studied product) but are included because they are typically provided with the total electricity and fuel consumption data. Other non-attributable processes such as infrastructure and equipment, corporate activities, transport of employees to and from work, etc. are excluded as either the information is not available or, while it is recognized that these non-attributable processes may have some environmental impacts that can be quantified using hybrid LCA methodologies, they are not significant contributors of impacts in agricultural systems and are thus not included.

Figure 1 further details the system under study, including raw materials production, the IGP primary and secondary production processes, packaging and then distribution to retailer. As noted prior, the use and end-of-life stages are not included here because they are not considered to differ between the IGP and PS processes.

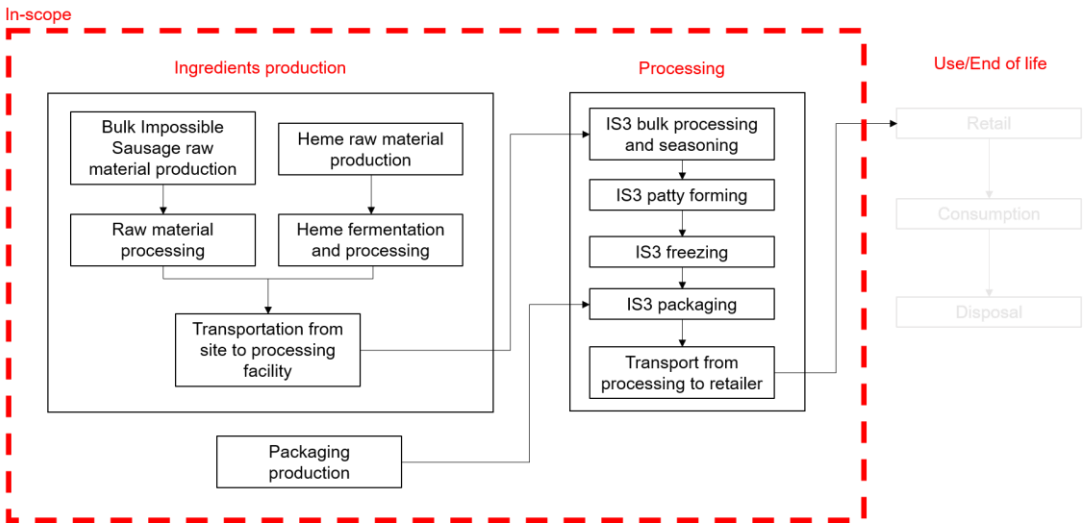

Figure 1 - Inventory boundary for the IGP scenarios (WSP analysis)

The in-scope life cycle stages of the IGP are identical to that described in the original LCA study (Impossible Foods, 2020) and are thus not discussed here.

3.3.2 GROUND PORK BOUNDARY DESCRIPTION

For the purposes of this addendum, the ground pork scenario will be labelled PS, to follow PS and 2 from the previous LCA (Impossible Foods, 2020). Analogous to the previous LCA study, pigs are produced in the US and China and processed to ground pork for local consumption. The products are meant to mimic the IGP, to be sold uncooked and frozen and in the form of a raw pork sausage patty (divided into individual servings that can be cooked). To achieve the functional equivalence of IGP, the PS has no additional flavouring.

The previous LCA (Impossible Foods, 2020) further details the system under study, including feed production, pig production (i.e., the pig rearing process and slaughter), pork product processing (meant to produce functional equivalence to the IS varieties), and then distribution to retailer. As noted prior, the use and end-of-life stages are not included here because they are not considered to differ from the IGP equivalent.

As noted above, overhead services are considered non-attributable but are included because they are typically included in the total electricity and fuel consumption data. The in-scope life cycle stages of the IGP are identical to that described in the original LCA study and are thus not discussed here.

3.4 SCENARIO DESCRIPTIONS

There are two scenarios that are relevant to this LCA addendum: one that compares IGP manufactured in the US with the pork analog produced in the US (PS) and one that compares IGP manufactured in the US and distributed to China with the PS produced in China. Each specific scenario is detailed in Table 2.

Table 2 – Product scenarios for this LCA

Scenario name	Impossible Foods scenario	Functionally equivalent scenario name	Functionally equivalent scenario
IGP – US	IGP that is produced in the US in 2021 and distributed uncooked, frozen to a typical US grocery store/retailer.	**PS - US**	Typical ground pork patty that is produced in the US in 2021 and distributed uncooked, frozen to a typical US grocery store/retailer.
IGP – China	IGP that is produced in the US in 2021 and distributed uncooked, frozen to a typical Chinese grocery store/retailer.	**PS - China**	Typical ground pork patty that is produced in China in 2021 and distributed uncooked, frozen to a typical Chinese grocery store/retailer.

3.5 CUT-OFF APPROACH

It is noted that for all scenarios, a mass-based cut-off criterion is used, where those cumulative inputs that comprise less than 0.5% of the total mass of the final products are not included in the quantification of the environmental indicators. This is consistent with the previous LCA study (Impossible Foods, 2020). For processes that are above that threshold where no modelled processes were available, proxies are used. Inputs where proxies were used are identified in Table 3.

3.6 INVENTORY DATE AND VERSION

This is the first version of the inventory comparing the IGP scenario against the PS scenario, but the inventory aligns with the previous study for IS1, PS and IS2, PS2 (Impossible Foods, 2020). The IGP production data are based on the most recent design and production data provided by Impossible Foods. For the pork scenarios, the inventories are based on representative industrial, market and literature data, where available.

3.7 TIME PERIOD AND GEOGRAPHIES OF THE INVENTORIES

This assessment is intended to be representative of the IGP and pig/pork product production in the US for the US-based scenarios and then representative of pig/pork production in China for the Chinese pork scenarios, during the year that the study is conducted (2020-1). Data and assumptions are intended to reflect current equipment, processes and market conditions. Data has been selected where possible to best match these geographic and temporal conditions, and the data quality of significant inputs was evaluated in the previous LCA (Impossible Foods, 2020). Additional data quality was not completed because the inputs and scenarios were not significantly different. The vast majority of sources of information for this report are all relevant and considered to represent the best available data and conditions in the industry. Certain processes may generate emissions over a longer period than the current year, but all data have been selected to represent current conditions, where practical.

For the global warming indicator, the 100-year time horizon global warming potentials (GWPs) without carbon feedback from AR5 are utilized (IPCC, 2014).

3.8 LAND-USE CHANGE IMPACTS

The literature review noted that GHG emissions from direct land-use changes from the use of crop lands to produce PBMA ingredients and crops for pig feed production may be significant (Reckmann, Blank, Traulsen, & Krieter, 2016). The quantification of GHG emissions for specific ingredients is sourced from the ecoinvent v3.7 (Wernet, et al., 2016) database and all crop-based ingredients include direct land occupation change impacts in their processes. Regardless, direct land-use change emissions may differ depending on the previous land occupation, the type of crop and the region in which the crops are grown.

4 LIFE CYCLE INVENTORY ANALYSIS

4.1 DATA SOURCES FOR IGP

Primary data for the stages controlled by Impossible Foods, such as the production of the bulk sausage, heme, and the processing stages, were provided by Impossible Foods and their suppliers/manufacturers. WSP has not audited the data in any way and relies on Impossible Foods to provide accurate data. For processes not controlled by Impossible Foods, such as transportation, pig feed production and pork distribution, secondary data were used from commercial databases and literature.

4.1.1 IGP – RAW MATERIALS PRODUCTION

The raw materials that constitute the IGP is divided into two primary parts: the bulk IGP mix and the ingredients to produce heme, which is described in more detail in Impossible Foods (2020).

A list of the ingredients and the associated modelled processes and database for the IGP is provided in Table 3. While only the broad categories of ingredients are shown here to ensure the privacy of proprietary information, the actual ingredients, or equivalent proxies, were used to model the IGP in the GaBi[2] software. All ingredients contributing less than 0.5% to the total mass of the product are excluded from the analysis. Specific ingredient contributions (i.e., amounts of each ingredient) are not provided to protect proprietary recipes.

Table 3 – List of IGP ingredients

IS ingredient list	Modelled dataset*	Database
Water	Tap water {ROW}, market for	ecoinvent v3.7
Soy protein concentrate	Used Agri-footprint dataset for foreground process but replaced all background processes with ecoinvent v3.1 processes (Blonk Agri-footprint BV, 2014)	ecoinvent v3.7 See Impossible Foods (2020) for further details
Coconut oil	Coconut oil, crude {PH} production	ecoinvent v3.7 See Impossible Foods (2020) for updated crop yields
Sunflower oil	Used Agri-footprint dataset for foreground process but replaced all background processes with ecoinvent v3.7 processes (Blonk Agri-footprint BV, 2014)	ecoinvent v3.7 See Impossible Foods (2020) for processes and updated crop yields
Methylcellulose	Methyl cellulose; via alkali cellulose; production mix, at plant	GaBi** database process

[2] Modeling for all systems in this study were conducted in the life cycle assessment (LCA) software GaBi®, owned by Sphera (http://www.gabi-software.com/america/index/).

Cultured dextrose, D-Ribose* **	Sugar, from sugarcane {GLO}, market for	ecoinvent v3.7
Tapioca starch	Tapioca starch {GLO}, market for	ecoinvent v3.7
Sodium hydroxide	Sodium hydroxide, without water, in 50% salutation state {GLO}, market for	ecoinvent v3.7
Soy leghemoglobin ("heme")	Proprietary product	See Impossible Foods (2020) for further details; ecoinvent v3.7 used for modelled processes
Mixed tocopherols (Vitamin E) ** **	N/A	
Soy protein isolate ** **		
Zinc gluconate ** **		
Spices ** **		
Salt ** **		
Natural flavours ** **		
Niacin ** **		
Thiamine hydrochloride (Vitamin B1) ** **		
Pyridoxine hydrochloride (Vitamin B6) ** **		
Riboflavin (Vitamin B2) ** **		
Vitamin B12 ** **		

*All processes were default allocation.**A GaBi-sourced process for methylcellulose was used because the only similar process in ecoinvent was for carboxy methylcellulose from synthetic/meat-based sources. ***These products were modelled using best available proxies in the ecoinvent v3.7 database. ****These products were not modelled directly because they cumulatively comprise less than 0.5% of the total product mass.

The environmental indicators of the production of the ingredients of heme as well as the manufacturing of heme are also included in this stage because they constitute an ingredient of the IGP. Details on the data sources for heme are described further in Impossible Foods (2020).

The transportation processes required to deliver the heme ingredients to the heme manufacturing facilities, freezer transportation of the heme to Oakland, California (CA) for the manufacturing of the IGP bulk mix, and then transportation of the IGP ingredients to the Oakland area for the IGP bulk mix are also included in this stage[3]. A

[3] This is one significant difference between this LCA and the previous (Impossible Foods, 2020): the bulk IGP production takes place in Oakland, CA whereas for IS1 and IS2, it took place in Chicago, IL.

fixed distance of 2,000 km by diesel truck was used for each US-based product transported to the Oakland-based IGP production facility. Any products that originated outside North America were modeled using a combination of truck and ocean transport using actual road and sea distances, respectively. Transportation of the heme product to the Oakland area for incorporation into the IGP bulk mix was modelled using truck transport and the actual road distance between the two cities.

4.1.2 IGP – FORMING AND FREEZING

The IGP mix undergoes a processing stage in the Oakland, CA area which includes forming and freezing of the product using pumps, motors, refrigerators and other equipment to prepare the product for packaging.

The data for this stage were collected by the manufacturer and modelled after the forming and freezing process for IS1 in Impossible Foods (2020). The data was based on the nameplate data for equipment used, as well as load factors and run-time cycles for when the product is produced; as such, the environmental indicator contribution from production within the facility is fully allocated to the IGP. The electricity grid for Oakland was modelled using the existing ecoinvent v3.7 California eGRID (CAMX) electricity process based on 2017 generation data.

It is assumed, as well, there is a loss of 5% by weight of the IGP from processing stage. Thus, the process was modelled with 5% of the output going to landfill. This is a conservative assumption as all efforts are made to conserve the product mass. Regardless, this approach was also used by Dettling, Tu, Faist, DelDuce, & Mandlebaum (2016) and replicated here (and in Impossible Foods (2020)).

4.1.3 IGP – PACKAGING

The IGP is packed using a flexible plastic pouch, suitable for use for frozen food applications, and this packaging is distributed to retail locations using corrugated cardboard secondary packaging. The amount of plastic film and corrugated cardboard used for the packaging is 23.1 g and 35.0 g, respectively, per kg of IGP. The packaging processes used are identical to that in Impossible Foods (2020), but it is noted that the quantity per functional unit of packaging has increased by 28% and decreased by 28% for the plastic film and corrugated cardboard, respectively.

4.1.4 IS – TRANSPORTATION TO RETAILER

The distribution to retailer for the IGP products differs between the US and China scenarios. For IGP going to US retailers, a fixed distance of 2,000 km of freezer truck travel was used to model the distribution to typical US retailers from the Oakland area. For IGP going to Chinese retailers, a fixed distance of 10,751 km of freezer freighter travel from Oakland to Shanghai, and a fixed distance of 1,500 km freezer truck travel within China was used to model the distribution to Chinese retailers from Oakland.

It is noted that the in-scope life cycle stages stop at the gate of the distributor; they do not include any activity at the retailer as it expected to be equivalent between the IGP and PS scenarios.

4.2 DATA SOURCES FOR PS

For the PS US and Chinese scenarios, data related to pig feed, pig rearing, pig slaughter, PS packaging, and PS transportation to retailer was identical to that used in Impossible Foods (2020).

4.3 ALLOCATION

Allocation processes used are identical to those used and discussed in Impossible Foods (2020).

5 LIFE CYCLE IMPACT ASSESSMENT

5.1 LCIA PROCEDURES AND CALCULATIONS

LCIA was carried out using characterization factors programmed into GaBi®. IMPACT 2002+ (Humbert, S., De Schryver, A., Margni, M., & Jolliet, O, 2012) was used to quantify global warming potential (GWP), aquatic eutrophication, and land occupation and ReCiPe Midpoint (H) v1.12/World Recipe H (RIVM, 2018) was used for water depletion.

5.2 LCIA RESULTS

The GaBi® software calculates LCIA results in its balance function and computes the environmental impact results according to pre-defined characterization methods in the selected LCIA methodology.

5.2.1 COMPARATIVE SCENARIOS

The environmental indicator results associated with the production of the IGP scenarios are lower than those of the PS scenarios for the four selected environmental indicators. For IGP and PS in the US, the results are provided in Table 4, on a per kg of food delivered to the retailer basis.

Table 4 – All scenario indicator results, per functional unit

Environmental indicators				
Scenario	Global warming (kg CO_2e)*	Aquatic eutrophication (g PO_4^{3-}-eq P-lim)*	Land occupation (m^2 org. arable-y)*	Water depletion (m^3)**
IGP – US	1.70	0.71	2.02	0.105
PS – US	7.31	1.48	5.92	0.549
Difference	-77%	-52%	-66%	-81%
IGP – China	1.93	0.71	2.02	0.105
PS – China	7.13	1.47	11	0.675
Difference	-73%	-52%	-82%	-85%

*Global warming, aquatic eutrophication, and land occupation indicators were quantified using the IMPACT 2002+ method. **Water depletion indicator was quantified using the ReCiPe Midpoint (H) method.

The global warming result for the IGP is 73 to 77% lower than that of the PS scenarios because of the contributions from manure management and additional crop usage for PS. The IGP is significantly lower in terms of GWP than the IS 1 because there is less heme (13% contribution to GWP), sunflower oil (10% contribution to GWP), and

coconut oil (7% contribution to GWP) in this recipe, which are all significant (5% or more) contributors to the GWP of the IS products.

The aquatic eutrophication result for the IGP is 52% lower than that of the PS scenarios because of the contribution of the crop farming and manure application to the US and Chinese pork scenarios. The IGP aquatic eutrophication result is primarily due to heme.

The land occupation result for the IGP is 66% to 82% lower than that of the pork scenarios; the land occupation result for all scenarios is primarily due to crop production. The primary contributor for the IGP is soybeans, sunflower oil, and coconut oil. The difference between the IS and IGP scenarios is due to the lower cropland requirements for the IGP in general. The land occupation for IGP is lower than that of IS1 and IS2 primarily because there is less heme, sunflower oil, and coconut oil in this recipe and lower overall contribution from those agricultural products to the functional units.

The water depletion result for the IGP is 81% to 85% lower than the PS scenarios, primarily because of water withdrawal from feed and pig production. The use of coconut oil and sunflower oil in the IGP contributes significantly to its water depletion result.

The comparative results are shown graphically in Figure 2. The highest values for each compared pair (i.e., for IGP – US and PS – US) for each environmental indicator are set at 100%.

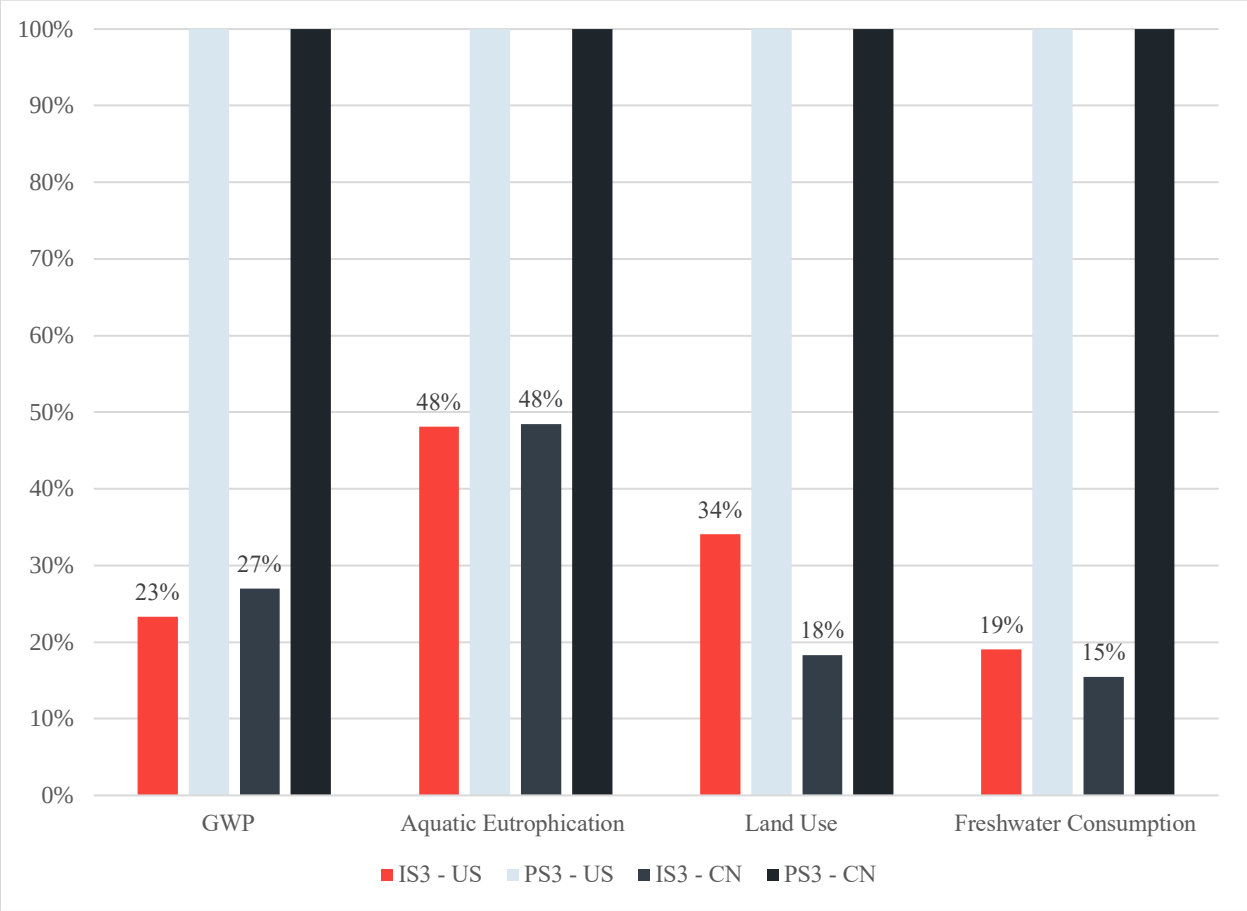

Figure 3 – Results of the IGP and PS scenarios under the four environmental indicators of concern

5.2.2 CONTRIBUTION ANALYSIS

Ingredient production contributes significantly to all selected environmental indicator results for the IGP scenarios. Distribution to retailer, for the Chinese scenarios only, has a significant contribution to the global warming result primarily because of the need to distribute the US-manufactured product to China. For land occupation, ingredient production contributes to close to 100% of the result. Packaging has a negligible contribution for all selected environmental indicators. The contribution of each life cycle stage for each of the indicators for all four IGP scenarios is presented below in Table 5.

Table 5 – All scenario indicator results, contribution of each life cycle stage to the overall environmental indicator

	Environmental indicators							
Life cycle stage	Global warming (kg CO_2e)*		Aquatic eutrophication (g PO_4^{3-} eq P-lim)*		Land occupation (m^2 org. arable-y)*		Water depletion (m^3)**	
	IGP-US	IGP-CN	IGP-US	IGP-CN	IGP-US	IGP-CN	IGP-US	IGP-CN
Ingredients	51%	45%	69%	69%	98%	98%	94%	98%
Production	29%	26%	27%	27%	0%	0%	4%	4%
Packaging	5%	4%	5%	5%	2%	2%	2%	2%
Distribution	14%	24%	0%	0%	0%	0%	0%	0%

5.2.3 PROCESS CONTRIBUTION ANALYSIS

Generally, the soy protein concentrate, sunflower oil, and coconut oil were significant (i.e., more than 5%) contributors to all four potential environmental indicators for the IGP – US and IGP – CN. No other processes were considered significant for land occupation and water depletion.

- For GWP, the heme, and distribution to retailer were also significant contributors;
- For aquatic eutrophication, heme and the CA electricity grid were also significant contributors.

5.3 LCIA RESULTS LIMITATIONS RELATIVE TO DEFINED GOALS

Other impact categories were not quantified in the results of the study because they do not serve to answer the questions defined in the goal and scope of the study for the intended audience stated in Section 1. As such, the application of the results of this study are limited to interpretations based on all potential environmental indicators included and cannot be generalized or applied to other environmental indicators.

5.4 DESCRIPTION OF PRACTICIONER VALUE CHOICES

The practitioner value choices have been limited to the selected LCIA. All results are presented on a mid-point basis, using the methods noted in Section 4.1; normalization and weighting are not used. Other impact categories have been excluded from the results because they do not answer the questions defined as the goal and scope for the intended audience in Section 1 of this report.

5.5 STATEMENT OF RELATIVITY

LCIA results are relative expressions and do not predict impacts on category endpoints, the exceeding of thresholds, safety margins, or risks. No grouping of impact categories has been performed; all impacts are presented at the mid-point level. LCIA impacts presented in this report are based on mid-point characterization factors (e.g., kg CO_2 equivalent for GWP), and this study does not refer to the ultimate damage to human health and the environment. For example, GWP may be a negative or a positive environmental impact depending on the conditions in locations where emissions occur. Since this study does not present end-point results, it does not draw any conclusions about the relative impact (positive or negative) for the categories considered by the study.

6 LIFE CYCLE INTERPRETATION

6.1 IDENTIFICATION OF RELEVANT FINDINGS

Based on the results presented in Section 4.2, the IGP has significant benefit over the PS among the four environmental indicators of concern. The IGP has slightly lower values for the four environmental indicators of concern than IS1 and IS2 because lower amounts of heme, sunflower oil, and coconut oil.

6.2 DATA QUALITY ASSESSMENT

Data quality for each process in the inventory boundary that contributed 5% or more of the potential environmental impact was evaluated in Impossible Foods (2020) and not re-detailed here as no new processes other than those where ecoinvent 3.1 were updated for ecoinvent 3.7 factors were updated. Where a change was made to the database, the data is more recent and the temporal data quality would undoubtedly improve; if there was no change made in the database, the data quality remains the same. The data quality for the only new process, the CA grid, is relevant within the past 3 years and data quality remains high. The reader is directed to this section in Impossible Foods (2020) for more details on general data quality for the models.

6.3 SENSITIVITY ANALYSIS

Inventory uncertainty is assessed on a qualitative and quantitative basis. The reader is directed to Impossible Foods (2020) for the uncertainty analysis for IS and PS (1 and 2). No new uncertainty was examined for the comparison of IGP and PS given the inputs and comparative results are so similar.

6.4 CONCLUSIONS AND RECOMMENDATIONS

This LCA compares the IGP, a PBMA produced in the US, with a PS produced in both the US and China. These products are considered to have functional equivalency because of their ability to satiate hunger, but also to provide similar quantities of nutrients.

The goal of this addendum to the previous Impossible Foods (2020) study is to compare the environmental profile made up of four environmental indicators, namely global warming, aquatic eutrophication, land occupation and water depletion, associated with a new IS variety (IGP) against a functionally equivalent PS variety (PS) and understand the extent to which the results for those particular environmental indicators for the IS variety is lower than for PS.

The following are the key findings from this work, focused on the assessments made here over IGP and PS:

- 1 kg of IGP shows a global warming result between 5.2 kg CO_2e and 5.6 kg CO_2e (73% and 77%) lower than 1 kg of PS, with the higher result for the IGP when it is distributed in China.
- 1 kg of IGP shows an aquatic eutrophication result between 0.76 g PO_4^{3-}eq and 0.77 g PO_4^{3-}eq (52%) less than 1 kg of PS, as it avoids some crop fertilizer and manure application emissions present in pig production.
- 1 kg of IGP shows a land occupation result between 3.90 m^2·org. arable·year and 8.98 m^2·org. arable·year (66% to 82%) less than 1 kg of PS. The largest contribution for the IGP is the heme and production of sunflower oil, which has a much lower yield than other crops in the ingredients.

- 1 kg of IGP shows a water depletion result between 0.44 m^3 and 0.57 m^3 (81% to 85%) less than 1 kg of PS. This is due to the much lower demand for agricultural irrigation for the IS ingredients than for the pig feed ingredients and high-water withdrawal (and low water returned) for the pig production and slaughterhouse stages.

For the IGP and PS products, the production of raw inputs (i.e., ingredients) is generally the main contributor to the environmental indicator results. For IGP, the ingredients contribute close to half of the global warming result, but distribution also contributes significantly to the IGP – CN because of the long distribution distance from the US to China. The ingredients (and their associated background processes) contribute much more significantly to the other three environmental indicator results.

In considering the results of this study, it should again be noted that while the nutritional content, an important feature of food and objective behind the consumption of food, has not been directly considered, a sensitivity analysis in Impossible Foods (2020) showed that had a caloric or protein-based functional unit been used, the conclusions would not have changed, although the land occupation indicator was especially sensitive to the caloric functional unit. The intention here is to portray an environmental comparison for the four environmental indicators of concern as accurately and clearly as possible, which can be used along with nutritional considerations, and other considerations such as taste, cost and convenience, in helping consumers make food choices.

In summary, the study has found that there are clear benefits, under the four environmental indicators of concern discussed in this study, to using IGP varieties studied in this work instead of PS.

6.5 ASSUMPTIONS AND LIMITATIONS

The evidence presented in this report and Impossible Foods (2020) is unique to the assumptions and practices of Impossible Foods and involves assumptions that are used by their production team to collect and record data. The reference scenarios have been specifically developed to be comparable to Impossible Foods production models as much as possible. The results are not intended to be a platform for comparability to other companies and/or other products. Even for similar products, differences in unit of analysis, life cycle stage profiles and data quality may produce incomparable results.

The LCA performed here in this addendum for Impossible Foods compares the production of IGP against PS produced in the US and China. Any conclusion described by this report must be considered only within the context of the study, with considerations of the data, assumptions and limitations used to arrive at those conclusions.

This LCA can be used to provide the results for the four selected environmental indicators for IGP studied in this work, as well as the primary contributors to those results. It also facilitates the identification of areas within the production process and ingredient list where improvements can be made as to those environmental indicators.

The limitations in this current study do not differ significantly from those described in Impossible Foods (2020) and the reader is directed there for that discussion.

7 REFERENCES

Blonk Agri-footprint BV. (2014). *Agri-Footprint - Part 1 - Methodology and basic principles* . Amsterdam, NL.

Dettling, J., Tu, Q., Faist, M., DelDuce, A., & Mandlebaum, A. (2016). *Assessing the environmental benefits of plant-based dietary choices through: a comparison of meal choices, and a comparison of meat products and MorningStar Farms® veggie products.* Qantis.

Humbert, S., De Schryver, A., Margni, M., & Jolliet, O. . (2012). *IMPACT 2002+: User Guide. Draft for version Q2.2 (version adapted by Quantis).* Quantis International.

Impossible Foods. (2020). *Final Report Impossible Sausage Made from Plants Life Cycle Assessment.* Impossible Foods Inc.

IPCC. (2014). *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.* Geneva, Switzerland: IPCC.

ISO. (2006, July 1). ISO 14044: Environmental management — Life cycle assessment - Requirements and guidelines. Geneva, Switzerland.

ISO. (2018). *Greenhouse gases — Carbon footprint of products — Requirements and guidelines for quantification.*

Reckmann, K., Blank, R., Traulsen, I., & Krieter, J. (2016). Comparative life cycle assessment (LCA) of pork using different protein sources in pig feed. *Archives Animal Breeding*, 27–36.

RIVM. (2018). *National Institute for Public Health and the Environment*. Retrieved from Ministry of Health, Welfare and Sport: https://www.rivm.nl/en/life-cycle-assessment-lca/recipe

USDA. (2019). *Agricultural Research Service*. Retrieved from USDA: https://fdc.nal.usda.gov/fdc-app.html#/food-details/172934/nutrients

USDA. (2019). *Economic Research Service*. Retrieved from Pork Statistics: https://www.pork.org/facts/stats/u-s-pork-exports/#exportsquad

Wernet, G., Bauer, C., Steubing, B., Reinhard, J., Moreno-Ruiz, E., & Weidema, , B. (2016). The ecoinvent database version 3 (part I): overview and methodology. *The International Journal of Life Cycle Assessment*, 21(9): 1218–1230.