

Online Appendix

Alternative Ingredients in Pet Food: A Guide to Emerging Proteins and Oils in Dog and Cat Food

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Appendix A: Extended Methods

This report used a multi-domain rapid scoping review approach to assess evidence across supply, sustainability, nutrition and health, and consumer acceptance. Initial searches of the peer-reviewed and grey literature were conducted primarily between November 2025 and January 2026, with targeted searches, backward citation searching, and additional evidence collection continuing through August 2026. Evidence was also supplemented by targeted review of industry and other relevant sources and discussions with industry experts. Search and assessment methods were adapted to the type and availability of evidence within each domain, as described below.

Supply

Targeted searches of peer-reviewed and grey literature were conducted to assess the supply and commercial readiness of each alternative ingredient. Searches examined key suppliers and production facilities, commercialization activity, regulatory status in major pet food markets, investment and capacity expansion, adoption by pet food manufacturers, and barriers and enablers to market development. Evidence was compiled from company websites and reports, press releases, trade publications and industry media, trade associations, academic literature, startup and investment databases, pet food manufacturer and retailer websites, and other relevant industry sources. Evidence was synthesized to assess the current maturity and availability of each ingredient and the factors likely to influence its near- and longer-term commercial development.

Production Volume Estimates

For ingredients without comprehensive published production data, relevant producers were identified through prior industry knowledge, targeted internet research, and AI-assisted searches using models with web access. Publicly available information was collected from company websites and reports, press releases, industry publications, academic literature, and other relevant sources. Where actual production volumes were unavailable, CFI developed base-case and upper-bound estimates using the best available evidence, including nameplate capacity, reported production rates, facility scale and operating status, recent sales, and commercialization activity. Assumed utilization rates were applied to reported or estimated capacity, with confidence assessed based on the recency, specificity, and reliability of the underlying evidence. Producer-level estimates were then aggregated to derive directional global production ranges. Because reported data are not consistently standardized across product forms, the resulting estimates should be interpreted as approximate. This method is referred to as “CFI estimation methodology” in Appendix B.

Price Estimates

Ingredient price estimates were primarily gathered from the IFEEEDER Pet Food Report (1). Where available, market price data reported by IFEEEDER were used to characterize prices for ingredients currently used in U.S. animal feed, while additional ingredient-level pricing data were obtained directly from the report authors, Decision Innovation Solutions (see Appendix C). These data were supplemented with publicly available supplier pricing, industry and trade sources, and other market information identified through targeted searches where necessary to address data gaps or characterize reported price ranges. For more novel

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ingredients where publicly available market pricing was limited, targeted searches were conducted to address data gaps, and techno-economic analyses (TEAs), primarily from the Good Food Institute (2), were used to provide estimates of production costs. Because ingredient prices can vary substantially with product form, quality, purchase volume, geography, supplier, and market conditions, reported prices were used to provide indicative current price ranges rather than standardized market prices.

Regulatory Review

A targeted regulatory review was conducted to assess whether each ingredient could currently be used in pet food across the selected major markets, the United States, European Union, Great Britain, China, and Brazil. Searches focused primarily on official legislation, regulatory registers, positive lists, ingredient definitions, authorizations, and guidance published by relevant national or regional authorities. These were supplemented, where necessary, by trade association guidance, regulatory summaries, company disclosures, and other secondary sources to clarify ingredient-specific approvals or identify recent regulatory developments. For each ingredient, the review considered whether its use was permitted, the relevant ingredient or product definition, any restrictions on species, production process, substrate, or intended use, and whether approval applied broadly to an ingredient category or only to a specific product or producer. Where regulatory status was unclear, terminology and ingredient definitions were cross-checked across multiple sources. The review reflects the regulatory position identified at the time of research and should not be interpreted as legal advice or as a substitute for jurisdiction-specific regulatory assessment.

Current Market Adoption: U.S. Case Study

Data Collection

In February 2026, CFI obtained data on U.S. pet food products containing the alternative ingredients assessed directly from the team at KibbleLab (3). The dataset contained 6,803 unique pet food products and their ingredient lists. Products were labeled by species (dog, cat), life stage (multiple, puppy, kitten, adult, senior), food type (wet, dry, supplement, topper, treat), and brand. CFI subsequently used an AI-assisted process to match brands with their corresponding manufacturers, enabling analysis of company-level trends.

KibbleLab also provided a list of ingredient package names used to identify alternative ingredients. Of these, 36 package names were considered relevant to the alternative ingredients assessed in this report (Table A1). A single ingredient category could appear under multiple package names. For example, brown seaweed could be listed using a general term such as “brown algae”, or a species name such as *Ascophyllum nodosum*. Package names were assigned to broader alternative ingredient categories based on KibbleLab ingredient definitions and additional review by CFI.

Data Analysis

Using the final list of ingredients, the total number and proportion of unique pet food products containing a given alternative ingredient was calculated. Frequencies were also

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differentiated by species, product type, brand, and manufacturer, to determine current patterns of product-level adoption.

Table A1: Alternative ingredients and package names from KibbleLab

Alternative Ingredient	Package Names
Algal oil	Algae DHA, Algae Oil, Golden Algae, Marine Algae Oil, Marine Microalgae, Marine Microalgae Oil, Microalgae Oil, Schizochytrium Sp. Alga
Algal protein	Chlorella, Spirulina, Whole-Cell Alga
Black soldier fly larvae (BSFL)	Black Soldier Fly Larva, Fly Larva, Soldier Fly Larva
Brown seaweed	Ascophyllum Nodosum, Bladderwrack, Brown Algae, Kelp
Red seaweed	Dulse, Red Alga
Yeast protein	Amber Yeast, Brewer's Yeast, <i>Candida jadinii</i> , <i>Candida rugosa</i> , <i>Cyberlindnera jadinii</i> , Distiller's Yeast, Grain Distillers Yeast, Kluyveromyces Marxianus Var. Lactis, Nutritional Yeast, <i>Saccharomyces cerevisiae</i> , <i>Schizosaccharomyces pombe</i> , Torula Yeast, Yeast

Sustainability

Data Collection

CFI conducted a scoping review of published original life cycle assessment (LCA) studies and reviews reporting environmental impacts for the alternative ingredients assessed. Only attributional LCAs with cradle-to-factory gate system boundaries were included to improve comparability across studies. The search prioritized studies evaluating ingredients produced for animal feed, but where feed-specific evidence was limited, studies of the same or comparable ingredients produced for other applications (e.g., human food) were included when production processes were considered sufficiently comparable. Multiple scenarios from the same study were included when they represented meaningful differences in production systems, such as energy source, feedstock, or production technology. Uncertainty bounds for the same scenario were not treated as separate observations. For a full list of inclusion criteria, see Table A2.

Table A2. Inclusion criteria for life-cycle assessment studies.

Inclusion criterion for LCA studies	Description
Ingredient	Assessed one of the alternative ingredients included in this report, or a relevant conventional ingredient used as a comparator.
Study type	Life cycle assessment (LCA) or other study providing sufficiently detailed life-cycle environmental impact estimates.
Intended application	Prioritized ingredients produced for animal feed. Where feed-specific evidence was limited, studies of the same or comparable ingredient for other applications were included where production processes were considered sufficiently comparable.
Scale	Data must represent prospective or retrospective alternative ingredient production at pilot scale or greater. Lab-scale systems were excluded

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System boundaries	Prioritized cradle-to-factory-gate assessments or studies with sufficiently comparable boundaries to characterize ingredient production.
LCA approach	Prioritized attributional LCA. Consequential approaches or scenarios relying on system expansion/substitution were excluded where they could not be separated from the reported result.
Environmental indicators	Reported quantitative results for at least one assessed indicator: GHG emissions, land use, or freshwater use.
Functional unit	Provided sufficient information to express impacts per unit of ingredient or otherwise convert results to per kg protein for proteins or per kg EPA+DHA for oils.
Environmental credits	Where possible, results were included without avoided-impact or environmental credits associated with substitution, system expansion, or carbon sequestration.
Data availability	Provided sufficient quantitative data and methodological information to extract and interpret an environmental impact estimate.
Publication type	Peer-reviewed studies were prioritized; other technical sources could be included where they provided sufficiently transparent and relevant LCA data.

Studies conducted only at the lab scale were excluded. Scenarios incorporating carbon sequestration or carbon capture accounting were excluded because of uncertainty regarding the magnitude, permanence, and attribution of these benefits. This exclusion mainly affected seaweed LCAs, which often include carbon sequestration benefits from seaweed production, but recent evidence suggests that such benefits are less ubiquitous than previously believed ([Berger et al., 2026](#)) (4). Studies that applied system expansion or consequential approaches (e.g., avoided burden allocation, carbon sequestration, biofertilizer substitution, combined heat and power credits, or carbon capture and storage) were also excluded when such credits could not be isolated because these approaches attribute impacts beyond ingredient production and are not directly comparable to attributional LCAs.

From the gathered LCAs, relevant information on functional units, geography, scale, system boundaries, production technology, temporal framing, feedstocks, energy sources, allocation methods, and production characteristics was collected to support interpretation of results. Data on three primary environmental indicators were extracted: greenhouse gas (GHG) emissions (kg CO₂eq), land use (m²a), and freshwater use (m³). Environmental results were aggregated to generate average and range estimates for each ingredient category.

Data normalization

To support comparisons across highly diverse ingredients and production systems, environmental impacts were converted to common functional units: 1 kg of protein for alternative proteins and 1 kg of EPA + DHA for alternative oils. Where protein or lipid content was not reported directly, values were estimated using comparable studies or established nutrient composition databases. The source and basis of each estimated value were recorded.

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Conventional comparators

Conventional ingredients were included as benchmarks for contextualizing the environmental impacts of alternative ingredients. Conventional protein comparators included chicken meat, chicken meal, and meat meals. Fish oil from wild-caught whole fish and byproducts was used as the conventional comparator for algal oil because it is the conventional animal-derived source of omega-3 fatty acids in pet food.

Environmental impacts for conventional animal-derived protein ingredients were collected primarily from Harvey et al. (2026) (5) (henceforth Harvey et al.), which estimated pet-food-relevant impacts using underlying data from Poore and Nemecek (2018) (6) (henceforth Poore and Nemecek). Average estimates from Harvey et al. (5) for GHG emissions, land use, and freshwater use per kg dry matter (DM) were combined with protein content on a DM basis for chicken, chicken meal, and meat meals to calculate impacts per kg of protein. To characterize variation in the conventional comparator impacts, CFI repeated the calculations developed by Harvey et al. (5), replacing the mean Poore and Nemecek (6) environmental impact values with the corresponding minimum and maximum values. The resulting estimates were used to construct ranges around the mean impacts originally reported by Harvey et al. (5). These ranges represent the effect of substituting the minimum and maximum underlying Poore and Nemecek (2018) impact values into the Harvey et al. calculation framework and should not be interpreted as statistical uncertainty intervals. They differ from the Monte Carlo uncertainty analysis reported by Harvey et al. (5), which incorporates uncertainty across multiple model inputs.

Of note, the conventional comparators derived from Poore and Nemecek (6) represent cradle-to-grave estimates and therefore are not fully equivalent in system boundaries to cradle-to-factory gate boundaries of alternative ingredients. This boundary difference may modestly bias comparisons against conventional ingredients because their estimates include additional downstream stages. However, ingredient production accounts for 82–95% of impacts across categories (5), suggesting that the effect on the overall comparison is limited.

The main analysis used economic allocation for conventional benchmarks, which distributes environmental impacts among meat and animal byproducts according to their relative economic value. This approach generally assigns a smaller proportion of production impacts to lower-value animal byproducts than to meat. The economic allocation approach reflects that livestock production is primarily driven by demand for products intended for human consumption rather than pet food (5). Economic allocation is also commonly used in LCAs of livestock production (7,8) and is consistent with the EU Product Environmental Footprint framework (5,9). However, results using this allocation method are sensitive to assumptions about the relative value of coproducts, which can vary across regions, production systems, and over time (10). Further, economic allocation provides a more conservative benchmark than mass allocation because it assigns a smaller share of livestock production impacts to lower-value animal byproducts.

Mass allocation distributes livestock production impacts among co-products according to their relative mass, assigning a greater share of impacts to animal byproducts than approaches based on their economic value. Mass allocation generally increases the estimated environmental impacts of animal byproducts, making alternative proteins appear

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more environmentally favorable by comparison. Because comparisons between meat and animal byproducts are sensitive to the method used to allocate livestock-production impacts, an alternative mass-allocation approach was also evaluated as a sensitivity analysis and is reported in Appendix E.

For the oil comparison, representative fish oil LCA estimates were compiled and standardized from the literature (11,12) to a common functional unit of one kilogram of EPA+DHA. Across all comparator analyses, conventional ingredients were used to provide context for the magnitude of alternative ingredient impacts; the comparisons do not imply nutritional equivalence or direct substitution within a pet food formulation.

Data Analysis

Normalized observations from eligible studies were combined to characterize the range of environmental impacts reported for each alternative ingredient. Mean, minimum, and maximum impacts were calculated across the compiled observations for each GHG emissions, land use, and water use (see Appendix D). Mean impacts for alternative proteins were compared with conventional protein benchmarks, chicken meat, chicken meal, and meat meals, while algal oil was compared with fish oil. Comparisons were interpreted in the context of methodological and production factors that can influence environmental impacts, including allocation approach, system boundaries, production scale, feedstock, and energy source.

Nutrition and Health

Data Collection

Nutrition and health evidence was identified through structured searches of the peer-reviewed literature conducted iteratively between November 2025 and January 2026, supplemented by backward citation searching where needed. Searches focused on experimental feeding trials evaluating nutrition- or health-related outcomes associated with the alternative ingredients assessed in this report. Study eligibility was informed by a PICO framework: healthy dogs or cats as the population, an alternative ingredient as the intervention, a control diet or baseline measurement as the comparator, and nutrition- or health-related measures as outcomes. Only peer-reviewed feeding trials were included.

Evidence was synthesized across four domains of basic nutritional suitability selected for their relevance to animal feeding, nutrition, and basic health: food intake and acceptance, nutrient digestibility and utilization, gastrointestinal outcomes, and body and physiological condition. Where reported, additional health-related outcomes associated with each ingredient, such as immune function, antioxidant markers, blood and serum profiles, and coat, oral, and eye health, were also captured. Evidence was synthesized by ingredient, species, inclusion level, and product form, with findings described narratively for dogs and cats based on the direction and statistical significance of differences relative to control diets.

Data Analysis

For each animal feed trial, reported outcomes were extracted qualitatively and grouped into the following outcome categories:

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1. palatability, food acceptance, and food consumption;
2. digestibility and nutrient utilization;
3. gastrointestinal function, stool and urine characteristics, fecal metabolites, and gut microbiota;
4. growth, body weight, and body condition;
5. immune function;
6. antioxidant and oxidative stress;
7. reproductive and developmental outcomes;
8. clinical chemistry;
9. coat, skin, and dermal health;
10. behavioral outcomes; and
11. oral and dental health.

The first four outcome categories (abbreviated as ‘food intake and acceptability’, ‘nutrient digestibility and utilization’, ‘gastrointestinal’, and ‘body and physiological condition’ outcomes) were prioritized for detailed synthesis because of their direct relevance to ingredient tolerance and nutritional performance.

For each outcome category, quantitative estimates for each measure (e.g. grams/day food intake on as-fed basis, apparent total tract digestibility of crude protein, fecal shaping score, average body weight gain) were recorded where available. Results were coded according to whether the alternative ingredient diet produced a statistically significant increase, a statistically significant decrease, or no statistically significant difference (compared to control). A finding of no statistically significant difference was described as “no detected effect”.

For dogs and cats, outcomes were synthesized narratively by ingredient and form. Where a range of dietary inclusion levels is reported, the range represents the minimum and maximum inclusion levels tested across the cited studies and does not imply that all intermediate levels were tested. These inclusion levels should not be interpreted as regulatory limits, established safe upper thresholds, or evidence that higher inclusion rates would necessarily cause adverse effects.

Significant changes to additional health-related outcomes (e.g. immune function and antioxidant markers) were extracted and described narratively to provide examples of potential health effects associated with alternative ingredients. Where possible, authors’ conclusions about the clinical relevance of the changes were included.

Methodological robustness was assessed using a custom four-feature appraisal covering comparison, allocation, measurement, and analysis/completeness, each rated Yes, No, or Unclear. Ratings for the first three features determined the provisional classification: limited (0–1 Yes), moderate (2 Yes), or strong (3 Yes), with strong robustness requiring a Yes for analysis/completeness; otherwise, the rating was capped at moderate. For studies of the same ingredient and form, robustness was summarized as the range across individual studies. The analysis also examined the highest ingredient inclusion levels evaluated without adverse observed health outcomes.

Consumer Acceptance

Consumer acceptance evidence was identified through a targeted literature search conducted iteratively between November 2025 and June 2026, supplemented by backward citation searching and relevant grey and industry literature. The search focused on studies of pet owners' perceptions, attitudes, acceptance, and purchase intentions toward the alternative ingredients assessed in this report, as well as evidence of observed purchasing behavior where available. Human-food studies and studies assessing pet palatability without measuring owner perceptions were excluded. Evidence was synthesized qualitatively to identify recurring barriers and enablers of consumer acceptance, including perceptions of safety and nutritional value, familiarity, disgust, perceived benefits, and sustainability.

Appendix B: Production Volume Estimates for Alternative Ingredients

Table B1: Production Volume Estimates for Alternative Ingredients. These estimates cover production across all sectors and should not be interpreted as directly comparable measures of ingredient volumes intended for or available to the pet food industry. See Appendix A for more details on the CFI estimation methodology.

Alt. Ingredient	Est. Global Production Volume	Estimates	Sources
Algal oil	~50,000-55,000 MT	Global algal oil production was estimated using non-public industry data presented to CFI on each major producer's approximate share of global EPA + DHA output. We converted these shares into total oil volumes using the reported or assumed EPA and DHA concentration of each producer's oil, then summed the resulting estimates across producers.	CFI estimation methodology
Algal protein	133,000 MT	Total 2024 production for all microalgae and cyanobacteria as classified by the Aquatic Sciences and Fisheries Information System (ASFIS).	(13)
Bacterial protein	~15,000-25,000 MT	Estimated producer-level output based on reported capacity, production rates, facility operating status, sales, and commercialization activity. See CFI estimation methodology below.	CFI estimation methodology
Black soldier fly	~30,000-40,000 MT	Estimated producer-level output based on reported capacity, production rates, facility operating status, sales, and	CFI estimation methodology

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		commercialization activity. See CFI estimation methodology below.	
Brown seaweed	18.5 million MT	Total 2024 production of brown seaweed as classified by the Aquatic Sciences and Fisheries Information System (ASFIS).	(13)
Cultivated meat	<500 MT	Estimated global production volume based on consultations with industry experts and available evidence on commercial-scale production.	CFI estimates with expert input from the Good Food Institute (14,15)
Mycoprotein	~50,000-60,000 MT	Estimated producer-level output based on reported capacity, production rates, facility characteristics, operating status, commercialization activity, and consultations with industry experts.	CFI estimation methodology with expert input from the Good Food Institute (15)
Red seaweed	21.2 million MT	Total 2024 production of red seaweed as classified by the Aquatic Sciences and Fisheries Information System (ASFIS).	(13)
Yeast protein	~500,000-1,000,000 MT	Estimated producer-level output of inactive yeast and yeast-derived products, excluding baker's yeast, based on reported capacity, production rates, facility characteristics, operating status, commercialization activity, and consultations with industry experts. Estimates span multiple product forms and end uses and should be interpreted as approximate global supply rather than volume available specifically for pet food.	CFI estimation methodology with expert input from the Good Food Institute (15)

Appendix C: Price Estimates for Alternative Ingredients

Table C1. Estimated price or cost of production ranges for conventional and alternative pet food ingredients. Where commercial prices were unavailable, estimated costs of production were used as an indicative lower bound for future market prices. Even on this basis, many emerging alternative ingredients remain more expensive than conventional ingredients such as chicken meat, chicken byproduct meal, and meat and bone meal, indicating that cost remains a major barrier to broader adoption. The price estimate for cultivated meat is highly uncertain.

	Price/Cost (USD/MT)					
Alternative ingredient	Low	High	Notes	Year(s)	Included species	Sources
Algal oil	6,000	15,000	Price	2025	Feed-grade algal oils	(11)
Algal protein	600	15,000	Price	2024	Spirulina, <i>Chlorella</i> , unspecified dried microalgae	(1)
Bacterial protein	1,300	11,000	Cost of Production	NA	<i>Cupriavidus necator</i> ; <i>Moorella thermoacetica</i> ; <i>Xanthobacter</i> sp. SoF1; hydrogen-oxidizing bacteria (HOB); methane-oxidizing bacteria (MOB), or methanotrophs, such as <i>Methylococcus capsulatus</i> .	(16,17)
Black soldier fly larvae	3,800	6,000	Price	2024	<i>Hermetia illucens</i>	(1,18)
Brown seaweed	300	1,000	Price; values >4,000 typically organic	2024	Generic brown seaweeds, including kelp	(1)
Cultivated meat*	37,000	100,000?	Cost of Production; Experts in cultivated meat suggest these	2025	Chicken cells	(15,19)

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			estimates are highly uncertain and could be as high as \$100,000 per MT			
Mycoprotein	3,800	5,300	Cost of Production	NA	<i>Fusarium venenatum</i> , <i>Paecilomyces variotii</i>	(2,20)
Red seaweed	300	2,900	Price	2021; 2022	Eucheumatoids, such as <i>Eucheuma cottoni</i> ; <i>Eucheuma spinosum</i> ; <i>Gracilaria</i>	(21,22)
Yeast protein	1,500	7,600	Price	2020; 2026	<i>Saccharomyces cerevisiae</i>	(23–26)
Chicken	900		Price	2024	NA	(1)
Meat & bone meal	400		Price	2024	NA	(1)
Chicken byproduct meal	700		Price	2024	NA	(1)
Fish oil	7,300		Price	2024	NA	(1)

Appendix D: Life Cycle Assessment Results with Economic Allocation for Animal-Derived Ingredients

Table D1: Environmental impacts of algal oil compared to fish oil. Results are reported per 1 kg EPA + DHA and use cradle-to-factory gate system boundaries. Values represent the mean, with minimum and maximum values shown in brackets. *n* indicates the number of estimates included in each calculation.

Type	Ingredient	GHG emissions (kg CO ₂ eq)	Land use (m ² a)	Freshwater use (m ³)
Conventional Oil	Fish oil From wild-capture whole fish and byproducts	9.9 [3.6, 20.4] <i>n</i> = 4 (11,12)	0.3 [0.0, 0.6] <i>n</i> = 2 (11,12)	0.0 [0.0, 0.1] <i>n</i> = 2 (11,12)
Alternative oil	Algal oil <i>Schizochytrium</i> sp. in heterotrophic systems	9.4 [3.4, 21.0] <i>n</i> = 18 (12,27,28)	9.6 [6.4, 14.2] <i>n</i> = 12 (28)	8.6 [2.0, 16.1] <i>n</i> = 12 (28)

Lower impact than fish oil – Mean impacts are lower than the mean impact of fish oil.

Higher impact than fish oil – Mean impacts are above the mean impact of fish oil.

No data – Insufficient evidence for comparison.

Table D2: Environmental impacts of alternative proteins compared with conventional protein ingredients. Results are expressed per 1 kg protein. Alternative protein estimates use cradle-to-factory gate system boundaries, while conventional protein benchmarks use the source-specific boundaries described in the Methods. Values represent the mean, which are reported with minimum and maximum estimates shown in brackets. *n* indicates the number of estimates included in each calculation.

Type	Ingredient	GHG emissions (kg CO ₂ eq)	Land use (m ² a)	Freshwater use (m ³)
Conventional proteins	Chicken meat (5,6)	57.8 [23.6, 278.6]	71.2 [37.3, 361.1]	3.9 [0.1, 27.5]
	Chicken meal (byproduct) (5,6)	2.3 [0.9, 11.2]	2.9 [1.5, 14.5]	0.2 [0.0, 1.1]
	Meat meals (byproduct) (5,6)	8.6 [3.5, 33.3]	24.9 [4.6, 279.0]	0.4 [0.0, 3.0]
Alternative proteins	Algal protein In phototrophic systems	106.5 [0.5, 464.2] <i>n</i> = 13 (29–32)	3.4 [0.1, 10.2] <i>n</i> = 9 (29–31)	0.5 [0.0, 1.1] <i>n</i> = 7 (29,30)
	Algal protein In heterotrophic systems	27.8 <i>n</i> = 1 (29)	9.1 <i>n</i> = 1 (29)	0.0 <i>n</i> = 1 (29)

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	Bacterial protein	7.0 [0.7, 15.1] <i>n</i> = 26 (31,33–36)	0.7 [0.0, 1.5] <i>n</i> = 18 (31,33–35)	0.1 [0.0, 0.3] <i>n</i> = 6 (33–35)
	Black soldier fly larvae	12.1 [1.1, 31.8] <i>n</i> = 29 (32,37–41)	2.2 [0.1, 14.0] <i>n</i> = 14 (37–40)	0.2 [0.1, 0.4] <i>n</i> = 2 (38,39)
	Brown seaweed	18.1 [2.2, 139.2] <i>n</i> = 39 (42–46)	—	—
	Cultivated meat	20.1 [9.0, 115.3] <i>n</i> = 49 (14,47–50)	9.5 [1.0, 16.7] <i>n</i> = 15 (47,49,50)	1.7 [0.3, 4.4] <i>n</i> = 12 (49,50)
	Mycoprotein	19.0 [1.9, 27.7] <i>n</i> = 17 (20,51–53)	4.8 [3.3, 9.7] <i>n</i> = 13 (20,51–53)	2.3 [0.3, 6.9] <i>n</i> = 13 (20,51,54,55)
	Red seaweed	54.1 [17.2, 169.6] <i>n</i> = 15 (46,56–58)	1.8 <i>n</i> = 1 (57)	2.6 [1.8, 3.0] <i>n</i> = 3 (56)
	Yeast protein	25.9 [0.3, 71.0] <i>n</i> = 12 (31,34,59)	4.7 [0.4, 16.4] <i>n</i> = 12 (31,34,59)	1.2 [0.0, 2.1] <i>n</i> = 11 (34,59)

Lower impact than animal byproducts – Mean impact is lower than the mean impact of at least one conventional animal byproduct.

Lower impact than chicken meat only – Mean impacts are higher than conventional animal byproducts, but lower than the mean impact of conventional chicken meat.

Higher impact than both chicken and ABPs – The mean reported impact is higher than the mean impact of conventional ingredients.

No data – Insufficient evidence for comparison.

Appendix E: Life Cycle Assessment Results with Mass Allocation for Animal-Derived Ingredients

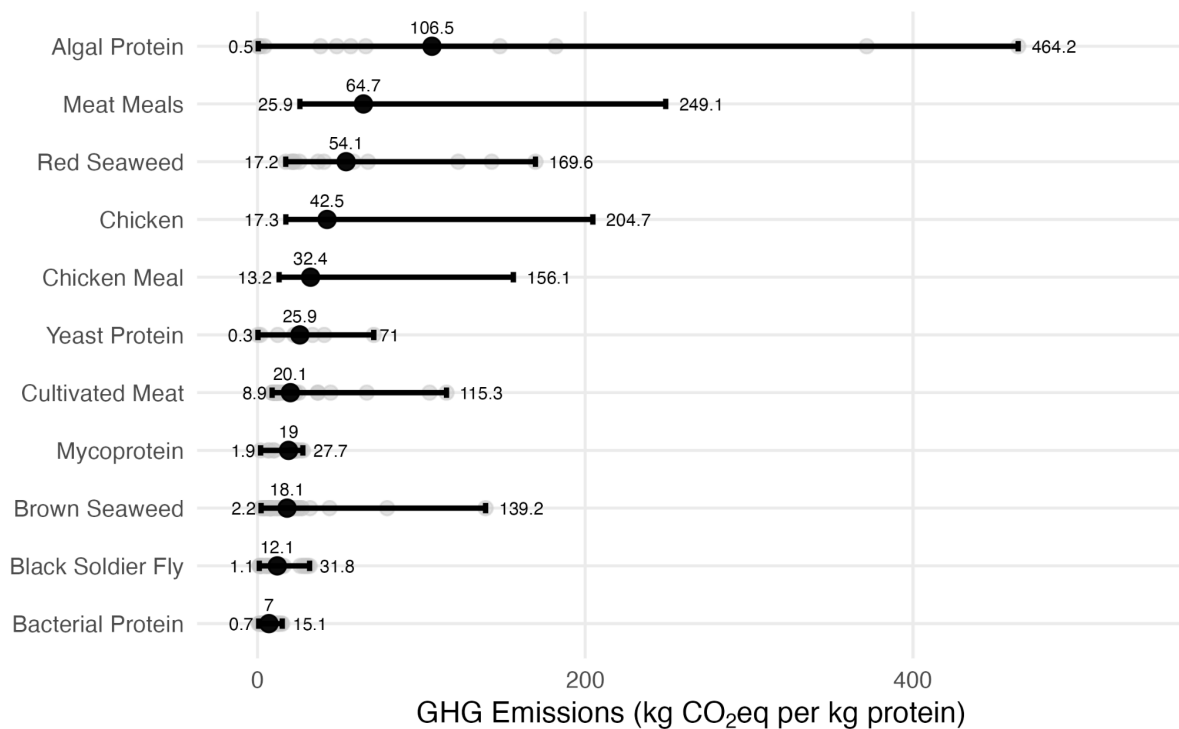


Figure E1: Greenhouse gas emissions of conventional and alternative protein ingredients used in pet food, per kg protein using mass allocation for animal byproducts. The bars represent minimum and maximum observed values in the literature, while circles indicate average emissions. Grey circles show all individual reported values. This figure presents the same comparison as Figure 9 in the main report, using mass rather than economic allocation for conventional animal-derived ingredients..

Appendix F: Additional References

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