gfi Europe

PAN International Physicians Association for Nutrition

# Where does plant-based meat fit in the UPF conversation?

A detailed guide to key topics and proof points for health professionals and stakeholders in protein diversification.

Image: Planted

# About this resource

This document was co-created by the Good Food Institute Europe (GFI Europe) and the Physicians Association for Nutrition (PAN), two non-profit organisations working to support the transition towards healthier, more sustainable diets.

It is designed to offer an objective and detailed but also accessible overview of the current discourse to stakeholders in protein diversification, including healthcare professionals, policymakers, researchers, health and sustainability NGOs and patient organisations.

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**Conflict of interest statement:** None of the authors or their affiliated organisations have any financial relationships with food companies or producers of plant-based meat.

This document is not intended to offer individual health guidance.

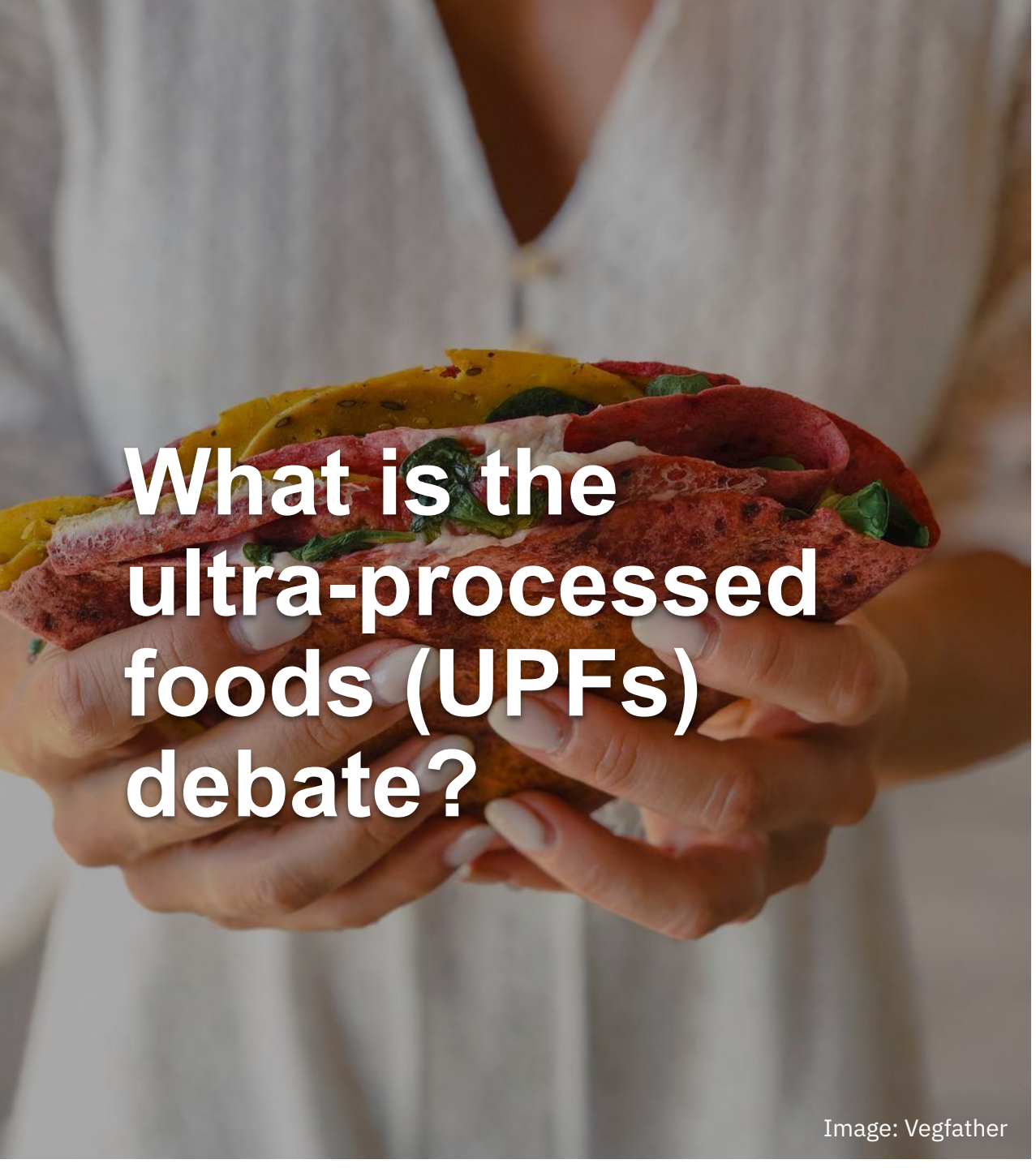
# Using this resource

This resource is intended to offer an evidence-based overview of research and key considerations relating to plant-based meat, ultra-processed foods (UPFs) and nutrition in the European context.

The sections divide the current debate into key topics, and explore the context and evidence for each.

To improve accessibility for non-specialist audiences, certain technical words (found in **bold**) are defined in the glossary on page 49.

## Contents:



# What is the ultra-processed foods (UPFs) debate?

Image: Vegfather

Research on ultra-processed foods (UPFs) shows that people with diets high in UPFs tend to have lower **diet quality** and higher rates of various diseases compared to people whose diets contain the least (Lane *et al.* 2024).

These **epidemiological** studies highlight that people with an increased disease risk are eating more convenient, cheap, high-calorie, and low-nutrient foods like sugary drinks, processed meats, cakes, and biscuits, while consuming fewer nutrient-rich foods like fruits, vegetables, legumes, and whole grains.

Most UPFs are high in calories and low in nutrients, but the term is not defined by nutritional criteria, and some UPFs have good nutritional value.

Research is ongoing to explore whether those eating the most UPF have higher disease risk because the food they eat tends to be higher in salt, fat and sugar or if some of this is caused by processing itself (Dicken *et al* NCT05627570, Hall *et al* NCT 05290064).

Because we don't know how much of the effect is caused by processing and how much is nutrient profile, there is debate about how UPF classifications should be used in policy and nutrition education, especially when assessing individual foods rather than overall diets.

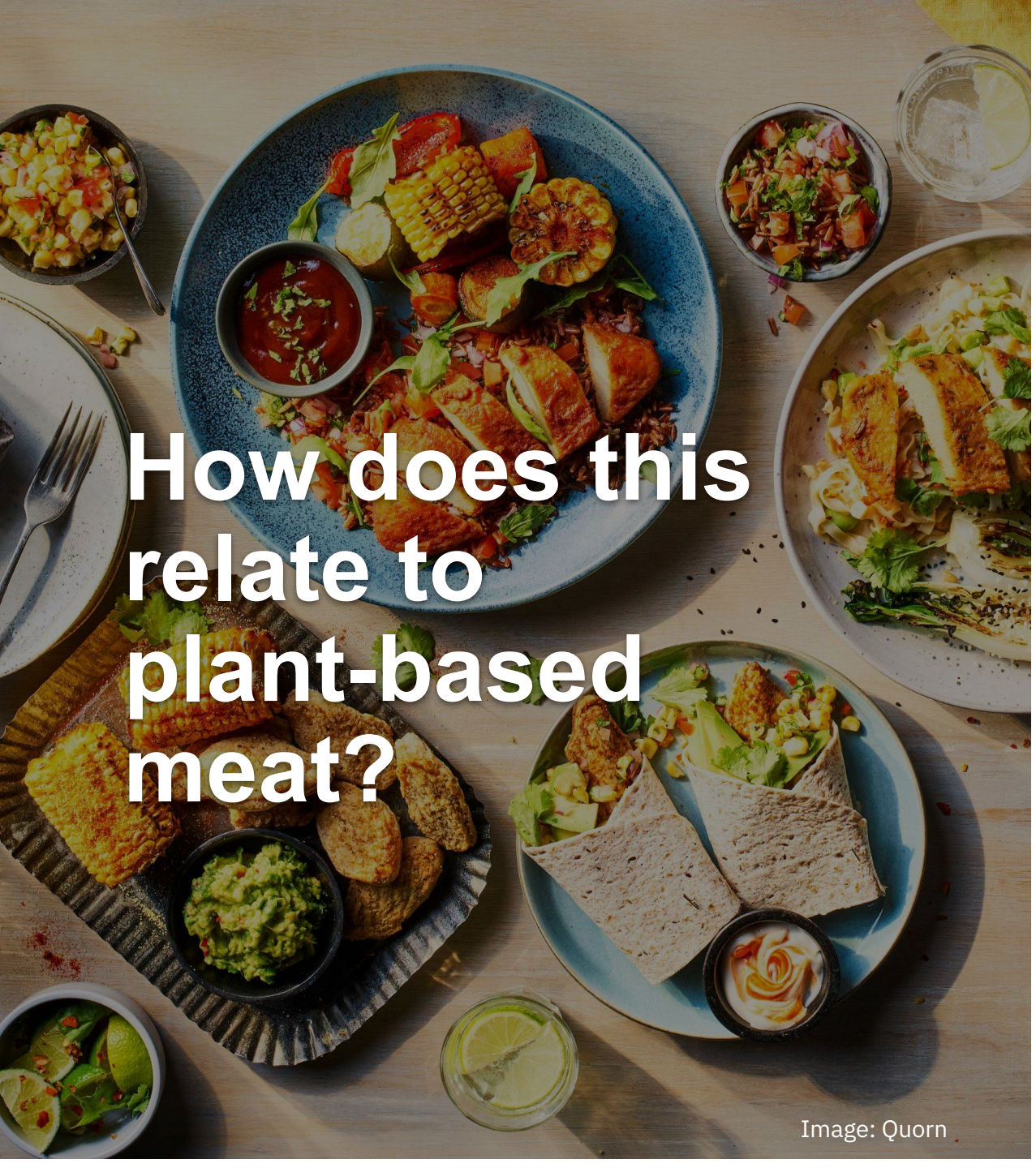



Image: Quorn

Plant-based meat is often considered UPF, but differs from the broader group in several ways.

Unlike most UPFs, plant-based meat is generally low in sugar and saturated fat, high in protein and a source of fibre (Espinosa *et al* 2024).

**Observational** (real-world) **epidemiological studies** that look at how different kinds of UPF affect health find that while people who eat the most UPF overall have increased health risks, risk is not uniform: some UPF types like processed meat and sugary drinks have particularly elevated risk, while others are not associated with increased risk (Dicken *et al* 2024, Cordova *et al* 2023).

**Experimental trials** suggest replacing conventional meat with plant-based meat can reduce **LDL (bad) cholesterol** and bodyweight (Fernández-Rodríguez *et al* 2025) – which are opposite to findings in the UPF group as a whole.

Plant-based meat could support shifts towards healthier, more sustainable dietary patterns (Messina *et al* 2023). However, because of the prevalent UPF discourse, their health profile is often misunderstood by the public. Health professionals, policymakers and public health communicators should collaborate to address this.

# What is plant-based meat, and how is it produced?

**In this section:**

- Plant-based meat is designed to replicate the taste and texture of animal meat using plant-based ingredients.
- The nutritional composition and processing level of plant-based meat varies by product and by country.
- The main points in production requiring processing are making the protein base, **texturisation** and added ingredients.
- Each of these can be done using higher or lower degrees of processing.
- Unlike most UPFs, plant-based meat is usually high in protein, a source of fibre (unlike conventional meat), low in saturated fat and low in sugar (Espinosa *et al* 2024).
- Inconsistent **fortification** with key nutrients and further reductions in salt content are two areas where the nutritional value of plant-based meat could be improved.

# Topic: What is plant-based meat?

| Statement | Further detail |
|---|---|
| Plant-based meat is designed to replicate the taste and texture of animal meat. | • Plant-based meat aims to replicate the taste and texture of conventional animal meat, differentiating it from traditional high-protein plant-based foods like **seitan**, tofu, and **Textured Vegetable Protein (TVP)**.<br>• Plant-based meat is made from plants (or sometimes fungi). The level of processing used varies by product *(see page 8)*. |
| Many different plant-based meat products are available in Europe today, with varied nutritional profiles and techniques used to make them. | • A pork hot dog has a very different nutritional profile from a chicken breast, and this variation is also true in plant-based meat.<br>• Different processing approaches can have advantages and disadvantages. For instance, processing can enhance digestibility of protein and **micronutrients** but it can also increase salt content (Cargo-Froom *et al* 2023, Samtia *et al* 2020, Xia *et al* 2024).<br>• Soy, wheat and pea protein **concentrates** and **isolates** are some of the most common bases for plant-based meat, made by extracting the protein from raw plant ingredients. This is called **fractionation** and can be done in several ways.<br>• Fermentation is also used to make protein ingredients, generally this involves less processing. **Mycoprotein** (protein from fungi like mushrooms and yeast) is already a common ingredient in the UK, and newer fermentation techniques can create meatier textures and **umami** flavours.<br>• **Texturisation** is also needed to create a meaty texture. **Extrusion** is a **texturisation** process commonly used to make plant-based meat, as well as many other widely eaten foods like shaped pasta and cereals. |
| Plant-based meat has particular public health potential to help reduce widespread overconsumption of processed meat, without requiring major behavioural change. | • Plant based meat is sometimes viewed as a niche food for those already following plant-rich diets like vegetarians, but its primary potential for public health lies in broader mainstream adoption.<br>• It has the largest potential for the many people who enjoy meaty meals, eat less fibre and more processed meat than recommended, and don't want to completely overhaul their diets, preferring options that fit within their existing daily routines.<br>• Increased availability of tasty, affordable, nutritious plant-based meat designed to appeal to these people could help improve **diet quality**, and make plant-based foods more accessible and less intimidating. |

# **Overview:** common processes used for high-protein plant-based foods

## Protein base

A core ingredient with high **protein density** is made, either by extracting protein from plants (eg soy, peas), or by growing fungi or other microorganisms with high protein content.

Separating the protein out from the raw ingredients is sometimes called **fractionation**, and the process used determines how much of the **food matrix** from the base ingredients remains in the end product.

## Texturisation

This protein base is then mixed with other ingredients (*see page 9*) and undergoes one of several possible processing steps to recreate the texture of conventional meat.

It is not easy to tell based on information on the packaging what **texturisation** processes have been used to make foods.

Lower

**Processing level**

Higher

**Examples:**

- Biomass fermentation
- Washing wheat flour
- Soy curds
- **Concentrates** and **isolates**
  - Dry **fractioning** (separation by weight)
  - Wet **fractioning** (separation by solubility)

*For more details on these processes, see appendix slide 41.*

**Examples:**

- Solid-state fermentation
- Pressing/moulding
- 3D printing
- **Extrusion**
- Fibre spinning

*For more details on these processes, see appendix slide 42.*

# **Overview:** other ingredients used in plant-based meat

UPFs on average have longer ingredient lists, so this metric is a common shorthand to identify them. However, ingredient lists are generally poorly understood by non-specialist audiences.

For example, the public are often wary of '**emulsifiers**', even though this term describes the ingredient's function rather than its composition, which varies. For instance, minimally processed ingredients like egg yolk are common **emulsifiers**. Other **emulsifiers** like **lectins** are present (but not added and therefore not labelled) in whole plant foods and animal meat (Pryme et al 2021, Radhakrishnan et al 2022), but can cause concern when listed as an ingredient.

All food ingredients approved by Europe's rigorous food safety processes have publicly available safety assessments on the **EFSA** website. Approvals require **experimental trials** and long-term health monitoring.

## Structural ingredients

Used to help replicate the texture of conventional meat.

A wide variety are used with different nutrient profiles and processing levels – ranging from plant fibres to ingredients like **methylcellulose**, lectins and gums, which are used as **emulsifiers** and binders to help mix the ingredients together without separating.

## Flavours and colours

These range from familiar ingredients like salt, herbs and beetroot extract to **artificial ingredients** made using chemical processes.

Traditional fermentation can be used to create complex umami flavours with low processing, and **precision fermentation** ingredients like **haem**, already used outside Europe, can deliver authentic meaty flavours and **bioavailable** iron.

## Fats and oils

A wide variety of fats and oils are used in different plant-based meat products, with varying processing levels and health attributes.

These range from unsaturated fats like rapeseed and olive oil, to saturated fats like coconut, palm, and **hydrogenated oils**, or a mix of these.

## Fortification

**Fortification** with nutrients like B12 and iodine is common in animal feed, leading to increased and consistent presence of certain nutrients in animal products.

Conversely, **fortification** is inconsistent in plant-based meat, meaning content of key nutrients like vitamin B12 varies. This should be improved.

# Topic: The nutritional composition of plant-based meat

| Point | Further detail |
|---|---|
| Significant variation exists between products and categories, but in general plant-based meat has a positive nutritional profile. | Compared to animal-based counterparts* and EU/UK **health claim** definitions, plant based meat is on average:<br>• Similar or slightly lower **caloric density**.<br>• A source of fibre, while conventional meat is not.<br>• High in protein. Similar to conventional meat in terms of % of calories from protein, but slightly lower per 100g.<br>• Neither low nor high in fat, similar to conventional meat.<br>• Low in saturated fat, unlike conventional meat.<br>• Low in sugar, like conventional meat.<br>• In most categories neither low nor high in salt.<br>• It should be noted that while the average seen here is roughly similar, large variation exists within categories: plant-based meat is higher in salt than unseasoned, unprocessed conventional meat, but similar or lower compared to processed conventional meat.<br>• See Appendix (*A3-A8*) for full breakdowns by product type and nutrient |

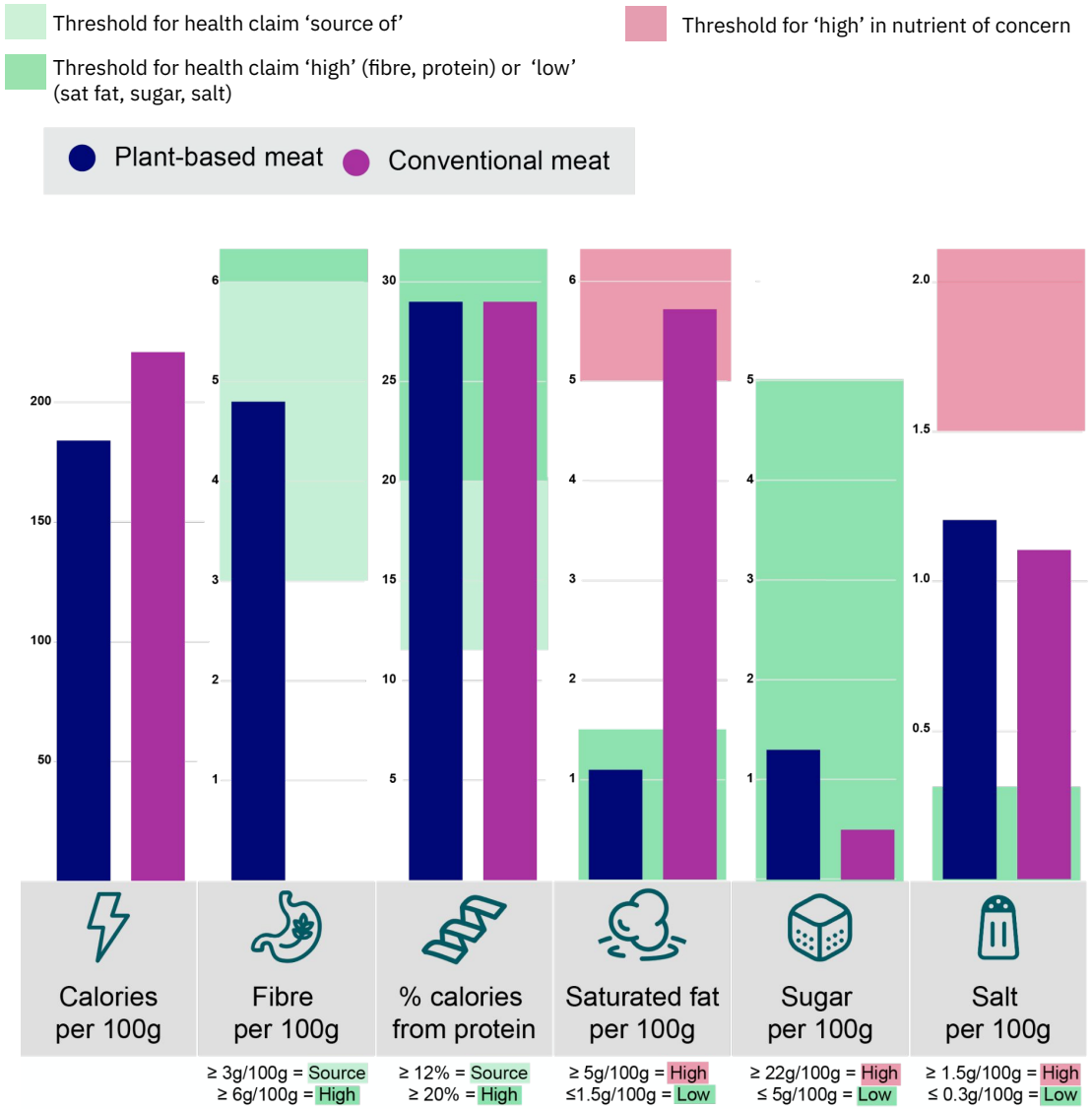



Figure created using median data from studies of nutritional composition of plant-based and conventional meat. Calories, fibre, saturated fat, sugar and salt taken from Espinosa et al 2024. Protein was not included in Espinosa et al, so protein figures were calculated based on values from other recent papers in Germany, Spain, Italy and the UK (Grea *et al* 2023, Heras-Delgado et al 2023, Cutroneo *et al* 2022, Alessandrini et al 2021).

*Unless otherwise specified, conventional meat comprises both processed and unprocessed products grouped together. Full breakdowns by product type can be found in the appendix.

# Topic: The nutritional composition of plant-based meat

| Point | Further detail |
| --- | --- |
| Plant based meat is sometimes, but not always, fortified with key nutrients. | • Animal feed is commonly fortified with key nutrients like B vitamins, calcium, iodine, long chain omega 3s and vitamin D (Neill et al 2021, ADHB 2025, Heutgen 2010). This **fortification** supports animal growth, but also boosts concentrations and consistency in animal products. Consequently, in European diets today fortified animal feed is a major source of several key nutrients. It is therefore important that plant-based options contain equivalent **fortification**.<br>• **Fortification** is used in certain staple foods like flour and margarine in several countries, and in some it is even mandatory (European Commission 2006, FAO 2021).<br>• In plant-based meat however, **fortification** is inconsistent both on the country and product level, which should be improved to increase the potential for these products to meet similar nutritional needs.<br>• **Fortification** rates are improving over time, and government guidelines such as those in the Netherlands (Voedingcentrum 2025) can significantly accelerate this:<br>  ○ A study in 2023 found 55% of Dutch meat alternative products were fortified (van Haperen 2023), which had risen to 75% in a similar study in 2024 (Gallani *et al* 2024).<br>  ○ Increases have been seen elsewhere but most countries have far lower prevalence of **fortification** overall. For instance, **fortification** rates in the UK grew from 5% to over 25% between 2021 (Alessandrini et al 2021) and 2024 (Gallani *et al* 2024).<br>• While **fortification** via animal feed is not listed as an ingredient, it is mandatory to specify it when added directly to food, thereby lengthening ingredients lists.<br>• Public understanding of UPF has made many people wary of longer ingredient lists, potentially penalising more nutritionally complete plant-based meat options. |

# What are Ultra-processed foods?

**In this section:**

UPFs are most commonly classified using the Nova framework (Monteiro *et al* 2019), which groups foods into four categories:

Nova 1 – foods made with minimal processing

Nova 2 – ingredients used in home cooking

Nova 3 – somewhat processed foods

Nova 4 – heavily (or 'ultra-') processed foods.

The Nova framework does not consider nutritional composition, it separates foods based on how they are made and used.

Plant-based meat is often considered Nova 4, but is very different from the most widely eaten UPFs both in terms of its nutritional profile and the dietary patterns it tends to fall into.

The Nova framework can be interpreted in two ways, and plant-based meat fits differently in each.

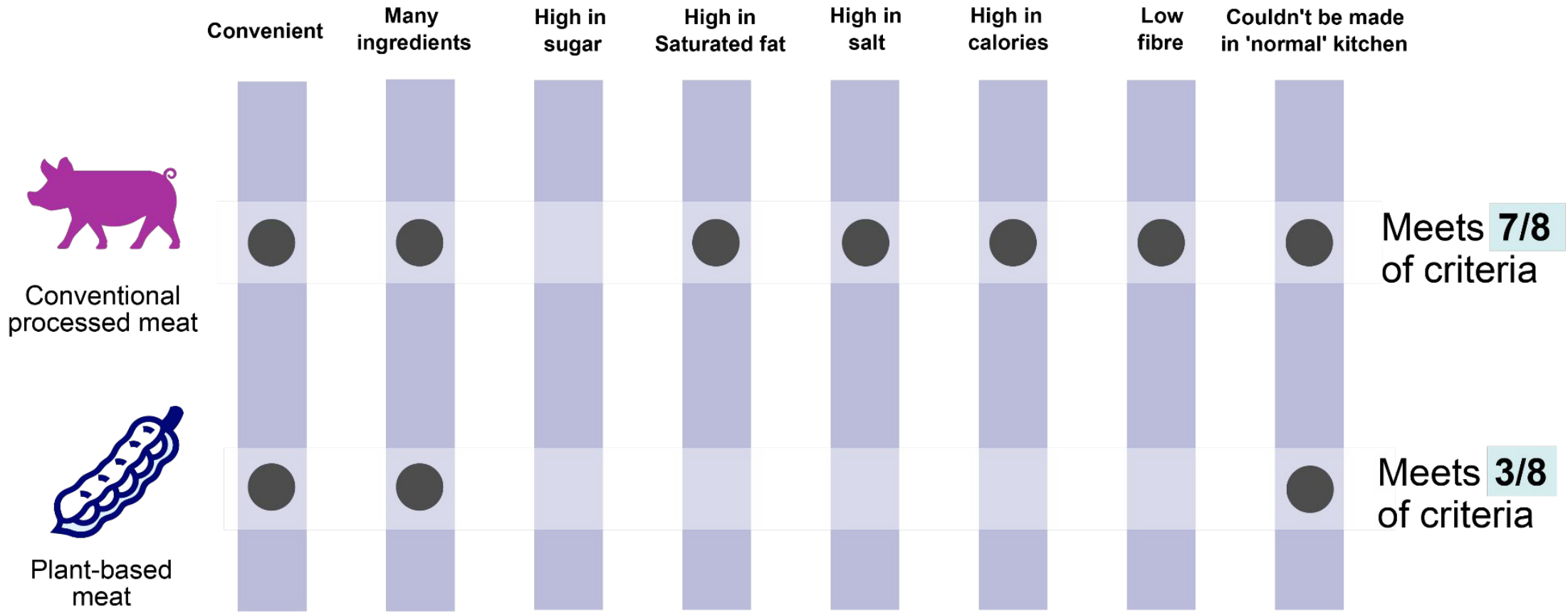
**Epidemiological**, identifying changing dietary patterns that are leading to increased rates of diet-related ill health. This is well researched.

**Food-level**, to assess healthfulness of individual foods. This research is still preliminary, and not yet strong enough to warrant interventions independent of well understood factors like nutrient profile (Lancet Gastroenterology & Hepatology 2024).

# Topic: Definitions of food processing using the Nova framework (Monteiro *et al* 2019)

| | Nova 1: Unprocessed or minimally processed foods | Nova 2: Processed culinary ingredients | Nova 3: Processed foods | Nova 4: Ultra-processed foods |
|---|---|---|---|---|
| Definition | • Minimal processing includes the removal of inedible or unwanted parts of a food source and very basic preservation like drying.<br>• Nothing should be added to the original food in this category at the point of sale. | • This category was broadly created to bridge the gap between ready-made and home cooked foods, comprising the ingredients like salt, herbs, sugar, vinegar and oil that are typically added during cooking but do not constitute the bulk of the meal.<br>• These foods are rarely eaten by themselves and unlike the other three categories are not grouped by the way in which they are made, but rather by the way in which they are used. | • Foods from group one that have been processed and/or combined with foods from group two, or group one or two foods that have been further processed into a final product that is ready to cook or eat.<br>• There are generally fewer processing steps and ingredients in processed compared to ultra-processed foods, although there can be overlap in the processes and ingredients used, and grey areas in dividing foods between the two. | • Foods with many ingredients in them and multiple processing steps that could not be recreated in a conventional kitchen.<br>• These foods are often (though not necessarily) high in salt, sugar and fat, low in fibre and **calorie dense**.<br>• These foods are generally convenient and quick to prepare, cheap, tasty, and often have plastic packaging. |
| Examples | • Fruits, vegetables, beans, mushrooms, tea, eggs, plain cuts of fresh meat (including red meat, white meat and seafood). | • Salt, peper, herbs, cooking oil, sugar, vanilla extract, bicarbonate of soda. | • Sourdough bread, canned chickpeas, tofu, tempeh, bacon, salted crisps, roasted nuts, yoghurt, cheese, pasta, mayonnaise. | • Energy drinks, hot dogs, chocolate bars, shaped salty snacks such as puffs or hoops, biscuits, breakfast cereals, milkshakes, protein powder, pre-packaged bread, plant-based meat. |

# **Overview:** Plant-based meat does not neatly fit with many of the characteristics often associated with UPFs – particularly compared to the conventional processed meat it often replaces.




Comparison based on GFI Europe analyses of median data from studies into macronutrient profiles of processed meat and plant-based meat in Spain (Heras-Delgado et al 2023), the Netherlands (van Haperen 2023), Sweden (Bryngelsson, *et al* 2022), the UK (Alessandrini et al 2021) and Germany (Grea et al 2023). Subjective categories of 'convenient' and 'could not be made in a conventional kitchen' were determined based on standard Nova definitions. Does not include unprocessed conventional meat.

# Topic: Food processing and the origins of the Nova framework

| Statement | Further detail |
|---|---|
| The origins of the Nova framework | • The most frequently used definition of UPFs is based on the Nova framework, developed by Brazilian **epidemiologist** Carlos Monteiro in 2009.<br>• He saw growing rates of obesity and diet-related ill health, and linked them to the rapidly changing eating habits in Brazil where, like many other places in the world, traditional home cooked foods were eaten less and less, replaced by cheap, mass produced convenience foods. He also saw that large food companies making these mass-produced foods were gaining more control over the food system.<br>• Monteiro argued that these foods, which were designed to be tasty, low-cost and were heavily marketed, were making people less healthy while increasing profits for food companies.<br>• This created a vicious cycle, where fresh, high-quality foods became less accessible, and people lost basic cooking skills needed to prepare healthy meals with vegetables, legumes, and other whole foods.<br>• Monteiro linked these trends and suggested that food processing itself – which makes food cheaper, tastier, and easier to consume – was a key reason for declining **diet quality.** |
| What specifically is meant by the term 'processing'? | • Based on this **epidemiological** observation at the population level, Monteiro sought to define 'processing' on the food level *(full definitions detailed on slide 13)*.<br>• This is a challenge, because processing covers a huge range of varied techniques, is a fundamental part of most food preparation, and is also demonstrably not linear in its impact on the 'healthiness' of a food: both over and undercooking food can undermine its nutritional value, and some cooking techniques like steaming can enhance it.<br>• Certain processing techniques like cooking, pasteurising, and fermenting have been used for centuries to improve the taste, safety and nutritional value of foods. Likewise, many unprocessed foods can be harmful in excess, like pork belly, which is high in saturated fat, or brazil nuts which have high levels of selenium.<br>• Consequently, the definitions of the four Nova categories are descriptive rather than quantitative, and have evolved over time, broadly seeking to draw a 'line of best fit'. |

# Topic: The two interpretations of the Nova framework

| Statement | Further detail |
|---|---|
| Interpretation 1: **Epidemiological**. What we eat (and by extension our health) is shaped by social influences and our food environment. Dietary patterns high in UPF are associated with poor health outcomes. Exploring these dietary patterns may offer insight into socio-political levers that can help improve people's **diet quality.** | • Most UPF research to date uses this **epidemiological** interpretation of Nova.<br>• Nova's inventor Professor Monteiro specialises in the **epidemiology** of obesity, and the Nova framework was initially developed on this basis to try and explain rising obesity rates.<br>• UPF studies using this framework typically use long-term, real world datasets. They generally compare the outcomes of those people whose diets contain the most UPFs, with those whose diets contain the least.<br>• Plant-based meat makes up a miniscule proportion of food eaten (0.2%). Meanwhile, the foods contributing the largest proportion of UPF calories in peoples diets come from foods already understood to be unhealthy in excess like pastries, buns, cakes and biscuits (10.8%) (Rauber *et al* 2024). Given these studies look at diets as a whole rather than individual foods, it is much more likely that high consumption of these less healthy foods – not the very small amount of plant-based meat eaten – drove the outcomes observed. |
| Interpretation 2: Food-level profiling. Processing level may alter the healthfulness of a food independent of nutrient profile. Understanding the impacts of different processes can help improve the nutritional value of foods. | • At the time of writing (May 2025), only a limited amount of research exists on the extent to which processing causes poor health outcomes independent of nutritional factors like salt, fat and sugar content, nor which processes are most harmful. Several studies exploring this are underway (Dicken *et al* NCT05627570, Hall *et al* NCT05290064) which assess the impacts of diets high in UPF versus diets high in minimally processed foods, using UPFs that meet national health recommendations / do not contain high levels of nutrients of concern.<br>• RCTs to date have suggested that harms of high UPF diets do at least in part come from nutritional factors such as **caloric density**, coupled with more processing-related considerations such as food texture and '**hyper-palatability**' encouraging over eating. (Hall *et al* 2019, Hamano *et al* 2024).<br>• We already know that the nutritional profiles of different plant-based meat products vary considerably (as with most types of food). The findings of this research on the ways in which processing can either reduce or improve the nutritional quality of food will likely be valuable to further enhance plant-based meat, eg, ways of better preserving some of the beneficial compounds in whole plant foods, optimising the types of fibre and fat present, or further reducing **caloric density**. |

# Topic: the Nova framework from a socio-political perspective

| Statement | Further detail |
| --- | --- |
| The **epidemiological** view of Nova also points to several social and economic trends at play in our food system, with relevance for plant-based meat. | ● A problem highlighted by proponents of the Nova framework is the decline of small independent food producers and businesses in an increasingly globalised food system.<br>○ This has already been seen in the conventional meat sector, with smaller family farms struggling to compete with larger companies in a globalised market.<br>○ Europe currently has a diverse and innovative ecosystem of plant-based meat companies, with many small startups and medium-sized independent players, alongside brands owned by larger food companies.<br>○ Amid the turbulence of the prevailing economic climate, however, smaller companies are particularly exposed to supply chain shocks and cost of living increases.<br>● It is therefore essential that public funding to support open-access research into these foods is increased, support is broadened for affordable access to scaling infrastructure, and barriers to entry are reduced for smaller, independent players to ensure the current diversity continues.<br>● This funding should also support exploration of plant-based meat's potential to support public goods, such as:<br>○ Further ways to enhance its nutritional profile.<br>○ Procurement pathways that provide robust demand for diverse crops grown by local producers to support rural communities and enhance food security.<br>○ Support for the proliferation of affordable products that are accessible to the groups of people most likely to benefit from them, rather than expensive niche products for small groups of people. |

# Topic: Strengths and limitations of the Nova framework

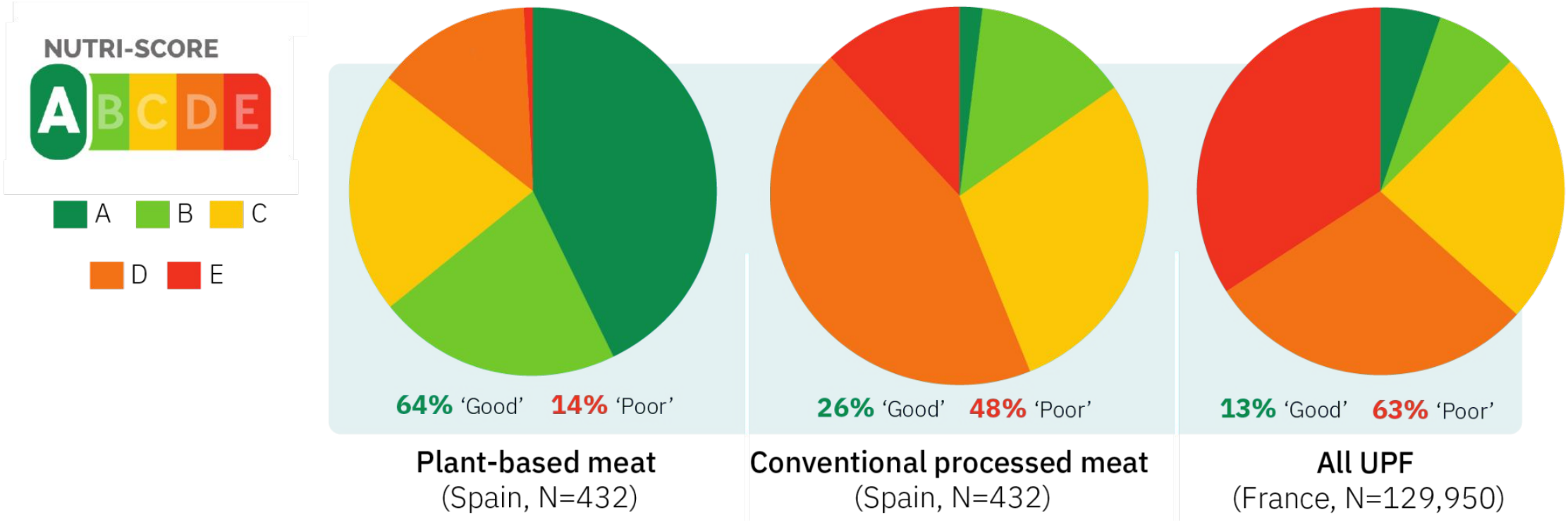
| Statement | Further detail |
|---|---|
| Strengths of the Nova framework | • Nova characterises the prevailing trends in our food system driving less healthy dietary patterns, and their relationship with demographic and social factors.<br>• The Nova framework clearly resonates with many people, and has effectively rejuvenated interest in well-worn but still very important nutritional guidance to increase consumption of vegetables, legumes and whole grains, and reduce dependence on convenient snack foods that are high in calories and low in nutritional value. It also encourages home cooked foods, which are generally (though not always) a healthier choice. (Mills *et al* 2017).<br>• Many proponents of the Nova framework point to its holistic nature as an intuitive pathway towards a healthier lifestyle more broadly, which is a fundamental part of successfully achieving lasting improvements in diet. |
| Limitations of the Nova framework | • Particularly among untrained public audiences, there is widespread confusion as to the definition of UPFs and the real-world implications of research for individuals. Behavioural changes prompted by warnings against UPFs have not been widely tested, and it is unclear whether Nova consistently incentivises the most beneficial dietary shifts.<br>• It is true that the average Nova 4 food is less healthy than the average Nova 1 food, but when accounting for nutrient composition, the differences in healthfulness between Nova categories is not well evidenced, and specific information about individual foods are more informative than membership in these broader categories.<br>• The few available datasets that have been used to try and validate Nova on a food-by-food basis are generally not designed to sort food by processing level. They also often rely on food diaries, which are generally an unreliable data source (Bajunaid *et al* 2025), that were taken before the Nova system was invented, and lack the granular details necessary to group foods consistently.<br>• Nova does not adequately distinguish between harmful, harmless, and helpful processing that food can undergo, which is particularly confusing for non-specialist audiences.<br>• Nova does not adequately account for nutritional variation derived from processing steps that take place in home cooking, such as boiling versus steaming vegetables (Lee *et al* 2017), or hotter versus cooler frying temperatures (Mavlanov *et al* 2025). |

# Topic: Alternatives to the Nova framework

| Statement | Further detail |
|---|---|
| Other frameworks have been developed to characterise UPFs. | • Several other metrics such as SIGA (Christodoulou *et al* 2020) and IUFoST (Ahrne *et al* 2025) have been developed aiming to offer more discrete (clear-cut) definitions for ultra-processing and tie them to nutritional characteristics, but these are at a far earlier stage of research (UK SACN, 2023). |
| Nutritionally-based frameworks that have been subject to robust scientific validation are also used to evaluate healthfulness of foods. | • Many tools to help people evaluate food healthiness are used across Europe in food labels or government scanning apps such as the **Nutriscore**, **NutrInform Battery**, **Nordic Keyhole**, **Schijf van Fijv** and **UK Traffic Light** systems.<br>• These have been developed to categorise foods on the basis of nutrient content, broadly recommending lower intakes of nutrients of concern – fat, salt, sugar – and increased intake of desirable nutrients like fibre.<br>• The factors chosen as the basis of these systems are similar, based on well established national nutritional reccommendations. There is however variation between each in how much each nutrient contributes to the overall score (eg fat versus sugar). Nutriscore is the most widely researched and so used here, but each has strengths and weaknesses.<br>• The lowest scoring foods in these systems frequently overlap with the UPF category, with one study of French products finding 63% of UPF fell in the 'poor' D-E categories, while only 13% fell in the 'good' A-B (Sarda *et al* 2024, *see page 20*). However, there are areas of divergence as UPFs with good nutrient profiles like packaged wholemeal bread and low-sugar fortified cereals are distinguished from well-established 'unhealthy foods'.<br>• Plant-based meat generally performs well against these criteria. One study surveying the nutriscore and Nova categories of products available in Spain found that 68% of plant-based meat products fell within the 'good' A-B range, while only 26% of conventional meat counterpart products did. *(*Heras-Delgado *et al* 2023*, see page 20)*.<br>• Results of studies exploring health outcomes linked to diets high in low-scoring foods according to Nutri-score find similar results to UPF studies, such as elevated **cardiovascular disease** risk (Deschasaux-Tanguy *et al* 2024).<br>• This highlights the need for **experimental data** to understand the balance between nutrient profiles and processing level in their contributions to health outcomes. |

# Independent of processing level, most (but not all) foods in the UPF category have a poor nutritional profile. Plant-based meat is a significant outlier, and generally performs favourably compared to both the processed conventional meat it replaces and the UPF group overall.

Comparison of Nutri-score ratings of plant-based meat compared to their conventional meat counterparts and the UPF group as a whole*




Reproduction of data published in Heras-Delgado S. et al (2023) and Sarda B *et al* (2024).

*Note: No single European study was available comparing Nova categorisations for plant-based meat, its conventional counterparts, and the UPF group as a whole, so overall UPF group data was taken from a separate study of products available in France. As such, the overall UPF group nutriscore findings may not be directly comparable, but are consistent with other research on Nutriscore and Nova alignment and so likely indicative.

# Existing research* on the effect of swapping conventional meat for plant-based meat

**In this section:**

- A small but growing body of evidence highlights several opportunities for public health through greater support for replacing conventional (particularly processed) meat with plant-based meat (Espinosa *et al* 2024).
- In particular, a **systematic review** and **meta analysis** of randomised controlled trials found a significant drop in **LDL (bad) cholesterol** and reductions in weight when conventional meat was swapped for plant-based meat (Fernández-Rodríguez *et al* 2025).
- Other studies have found **diet quality**, **microbiome** and gut health benefits (Farsi *et al* 2023, Bottin *et al* 2016).
- These results make sense given plant-based meat has higher fibre and lower saturated fat than conventional meat (Hartley *et al* 2016, Hooper *et al* 2020).
- These findings are very different from those seen in studies of health outcomes linked to high intake of foods in the overall UPF category.
- More research is still needed.

*As of 20 May 2025

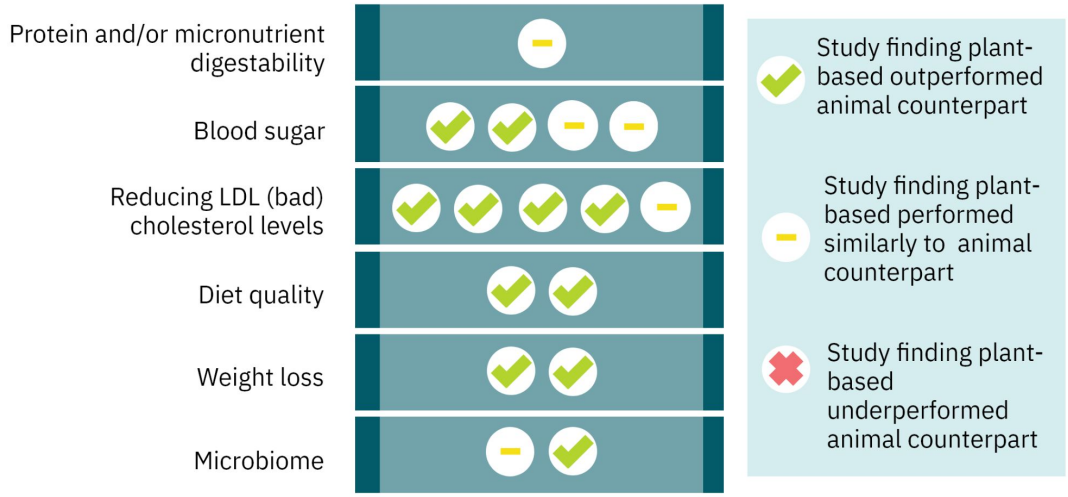
# Existing research on the effect of swapping conventional meat for plant-based meat

| Point | Further detail |
|---|---|
| Plant-based meat can help expand uptake of plant-based foods alongside other strategies. | • Initiatives supporting greater intake of whole plant foods are sorely needed. However, these initiatives alone may not be enough to meet environmental and health targets within timeframes needed.<br>• Many people want to eat more plants, but not always for the same reasons – some are motivated by health, others by environment, others by a mix of these and other factors (Reuzé *et al* 2023). These people also come from a range of circumstances and backgrounds, meaning it's highly likely that different approaches will work better for different people, and driving change will require a combination of complementary approaches.<br>• Despite being a much more recent invention, in the UK plant-based meat volume sales are over 7 times that of tofu, and 5 times that of traditional bean burgers (GFI Europe, 2024), suggesting it may appeal to broader groups of people.<br>• Plant-based meat and similar foods like plant-based dairy, in addition to offering **fortification** opportunities, require only small behavioural shifts for adoption. They therefore make it easier for people to initiate and maintain more plant-centric dietary patterns (Alae-Carew, 2022). |
| Studies exploring the impacts of replacing conventional meat with plant-based meat are generally in line with what we would expect based on their nutritional profiles. | • Several **experimental trials** have explored the impact of replacing conventional meat with plant-based meat. Findings are broadly positive, particularly for reduction of LDL (bad) cholesterol and weight loss (Fernández-Rodríguez *et al* 2025, *see page 24 and 25*).<br>• Three independent **systematic reviews**, of which one was a **meta analysis**, were published in 2024 synthesising the findings from these studies, from researchers based in Spain, the UK and Canada (Fernández-Rodríguez *et al* 2025, Espinosa *et al* 2024, Nagra *et al* 2024).<br>• Most studies were small, but results were generally consistent, and match what would be expected based on their fibre content and fat profile compared to conventional meat (Hartley *et al* 2016, Hooper *et al* 2020).<br>• While more, longer, and larger trials would be helpful to better understand these opportunities, there is already compelling evidence that plant-based meat can support the shift towards healthier, more sustainable diets. |

# Existing research on the effect of swapping conventional meat for plant-based meat

| Point | Further detail |
|---|---|
| Clinical trials have shown promising findings in several areas. | Trials suggest plant-based meat may help:<br>• Reduction of LDL (bad) cholesterol *(see page 24)*.<br>• Weight loss in people with overweight *(see page 25)*.<br>• Benefits for gut health and lower colorectal cancer risk (Farsi *et al* 2023).<br>• Maintain **muscle protein synthesis (MPS)** rates in older people similarly to conventional meat (Domić *et al* 2024). This contrasts with findings of lower MPS rates from meals with matching calorie and protein content using only whole food plant-protein sources compared to meat (Pinckaers *et al* 2024). This difference is likely due to improved **protein quality** achieved through certain processing techniques. |
| Further research is needed to better understand the generalisability of results to date. | Key areas for future research should include:<br>• Comparisons of impact by protein ingredient base, and the contribution of key factors such as fibre or **protein density** to outcomes. Most current studies use **mycoprotein**-based and soy-based products, with the strongest benefits seen in **mycoprotein**.<br>• More studies into the relative **bioavailability** of protein and key **micronutrients** in plant-based versus conventional meat.<br>• Studies to understand the effectiveness of plant-based meat in supporting adherence to healthier dietary shifts compared to other approaches, and whether benefits persist on longer time frames.<br>• Studies in more diverse populations to understand if variation exists in impacts between different demographic groups.<br>• Explorations in populations with specific dietary needs such as athletes, older people, or those looking to maintain lean mass during weight loss, for whom nutrient density, protein and fibre are key considerations. |

**Key findings from interventional trials exploring the health impacts of replacing animal meat with plant-based meat**



# **Overview:** Fernandez-Rodriguez et al, 2024. The first major systematic review and meta analysis of randomised controlled trials on plant-based meat.

The American Journal of Clinical Nutrition xxx (xxxx) xxx

The American Journal of CLINICAL NUTRITION

journal homepage: https://ajcn.nutrition.org/

Original Research Article

## Plant-based meat alternatives and cardiometabolic health: a systematic review and meta-analysis

Rubén Fernández-Rodríguez [1], Bruno Bizzozero-Peroni [2,3,*,†], Valentina Díaz-Goñi [2,†], Miriam Garrido-Miguel [2,4,5], Gabriele Bertotti [6,7], Alberto Roldán-Ruiz [6,7], Miguel López-Moreno [6,7]

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ABSTRACT

**Background:** Plant-based meat alternatives (PBMAs) are emerging in global markets. However, the effects of substituting meat for PBMAs on cardiometabolic health are uncertain.

**Objectives:** This study aimed to determine the effects of replacing meat consumption by PBMAs on cardiometabolic parameters in adults.

**Methods:** Five databases were systematically explored from inception to July 2024, searching for RCTs assessing the effects of replacing meat consumption by PBMAs on cardiometabolic parameters in adults without cardiovascular diseases. Meta-analyses were conducted when ≥4 studies addressed the same outcome (i.e. blood lipids, blood pressure, fasting glucose, and body weight). Pooled raw mean differences (MDs) with their 95% CIs were estimated using a random-effects method. Sensitivity analyses were conducted to assess the robustness of our estimates.

**Results:** Eight publications from 7 RCTs comprising 369 adults (60% females; mean age range: 24–61 y) were included. The substitution of PBMAs for meat was associated with significant reductions in LDL-cholesterol: −0.25 mmol/L (95% CI: −0.42, −0.08 mmol/L; $I^2 = 65.8\%$ $n = 7$), total cholesterol (TC): −0.29 mmol/L (95% CI: −0.52, −0.06 mmol/L; $I^2 = 64.8\%$; $n = 6$), and body weight: −0.72 kg (95% CI: −1.02, −0.42 kg; $I^2 = 0\%$; $n = 5$). No significant changes were shown in HDL-cholesterol, triglycerides, blood pressure, or fasting glucose concentrations. Sensitivity analyses considering mycoprotein-based alternatives showed a significant reduction in LDL-cholesterol (MD: −0.37 mmol/L; 95% CI: −0.61, −0.13 mmol/L; $I^2 = 52.5\%$; $n = 4$), and TC (MD: −0.39 mmol/L; 95% CI: −0.56, −0.21 mmol/L; $I^2 = 0\%$; $n = 4$).

**Conclusions:** Our findings suggest substituting PBMAs for meat for ≤8 wk lowered TC (6%), LDL-cholesterol (12%), and body weight (1%) in adults without cardiovascular diseases. PBMAs may facilitate the transition to a plant-based diet, but long-term studies are needed to evaluate their cardiometabolic effects.

This trial was registered at PROSPERO as CRD42024556191.

*Keywords*: plant-based meat food, meat substitutes, cardiovascular disease, diet, planetary health

### Introduction

Planetary health concerns play a pivotal role in current dietary guidelines [1,2] and international reports [3,4], promoting a reduction in animal-based foods, especially red and processed meat whereas increasing plant-based food intake [5]. High consumption of red and processed meat has been linked to increased risk of different chronic noncommunicable diseases [6], including cardiovascular diseases (CVDs) and diabetes, as well as overall increased risk of all-cause mortality [7]. Added to the lower environmental impact [8,9], a recent microsimulation study estimated that reducing or replacing meat consumption with plant-based foods could result in lower risk or prevalence of noncommunicable chronic diseases [6], including CVDs [6], metabolic disorders [10,11], and cancer [6].

*Abbreviations:* CRP, C-reactive protein; CVD, cardiovascular disease; PBMA, plant-based meat alternative; TC, total cholesterol; TG, triglyceride; UPF, ultraprocessed food.

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† BB-P and VD-G contributed equally to this work.

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Source: Rubén Fernández-Rodríguez, Bruno Bizzozero-Peroni, Valentina Díaz-Goñi, Miriam Garrido-Miguel, Gabriele Bertotti, Alberto Roldán-Ruiz, Miguel López-Moreno. Plant-based meat alternatives and cardiometabolic health: a systematic review and meta-analysis. The American Journal of Clinical Nutrition 2025. Volume 121, Issue 2, February 2025, Pages 274-283 doi: https://doi.org/10.1016/j.ajcnut.2024.12.002

**Number of participants:** Seven randomised controlled trials reported across eight research papers, covering 369 adults.

**Study design:** Data was pooled from included trials, exploring changes in indicators of cardiovascular health associated with the substitution of conventional meat with plant-based meat for 1-8 weeks, to understand consistency and extent of outcomes across trials.

**Outcomes examined:** Total, LDL (bad) and HDL (good) cholesterol, body weight, fasting blood glucose, and blood triglycerides.

**Key findings:** Swapping conventional meat for plant-based meat was associated with **significant reductions in LDL-cholesterol, total cholesterol and body weight.** The overall reduction in LDL cholesterol* was 12% (-0.25 mmol/L), and largest in **mycoprotein** interventions (-37 mmol/L).

No significant differences were observed in other outcomes studied.

*For context, reductions of 0.2-0.4 mmol/L represent ‘moderate’ reductions. This places plant-based meat on the higher end of effectiveness as a dietary intervention to lower LDL (Schoeneck *et al* 2021). The European Society of Cardiology recommend LDL should be ‘as low as possible’ for all populations, and are particularly important for those with high risk of **cardiovascular disease.** Reductions achievable through diet are smaller than with medicines, which can reduce levels by over 60% (ESC/EAS, 2019). If the reductions seen in these trials were maintained over a long period of time they could contribute to reduced **cardiovascular disease** risk (Penson *et al*, 2020).

# **Overview:** RE-MAP trial, 2022. A large, publicly funded RCT on the effectiveness of plant-based meat as an intervention to reduce overconsumption of meat.

See corresponding editorial on page 1263.

Replacing meat with alternative plant-based products (RE-MAP): a randomized controlled trial of a multicomponent behavioral intervention to reduce meat consumption

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ABSTRACT

**Background:** Reducing meat consumption could protect the environment and human health.

**Objectives:** We tested the impact of a behavioral intervention to reduce meat consumption.

**Methods:** Adult volunteers who regularly consumed meat were recruited from the general public and randomized 1:1 to an intervention or control condition. The intervention comprised free meat substitutes for 4 weeks, information about the benefits of eating less meat, success stories, and recipes. The control group received no intervention or advice on dietary change. The primary outcome was daily meat consumption after 4 weeks, assessed by a 7-day food diary, and repeated after 8 weeks as a secondary outcome. Other secondary and exploratory outcomes included the consumption of meat substitutes, cardiovascular risk factors, psychosocial variables related to meat consumption, and the nutritional composition of the diet. We also estimated the intervention's environmental impact. We evaluated the intervention using generalized linear mixed-effects models.

**Results:** Between June 2018 and October 2019, 115 participants were randomized. The baseline meat consumption values were 134 g/d in the control group and 130 g/d in the intervention group. Relative to the control condition, the intervention reduced meat consumption at 4 weeks by 63 g/d (95% CI: 44–82; $P < 0.0001$; $n = 114$) and at 8 weeks by 39 g/d (95% CI: 16–62; $P = 0.0009$; $n = 113$), adjusting for sex and baseline consumption. The intervention significantly increased the consumption of meat substitutes without changing the intakes of other principal food groups. The intervention increased intentions, positive attitudes, perceived control, and subjective norms of eating a low-meat diet and using meat substitutes, and decreased attachment to meat. At 8 weeks, 55% of intervention recipients identified as meat eaters, compared to 89% of participants in the control group.

**Conclusions:** A behavioral program involving free meat substitutes can reduce meat intake and change psychosocial constructs consistent with a sustained reduction in meat intake. *Am J Clin Nutr* 2022;115:1357–1366.

**Keywords:** meat substitutes, vegetarian, meat, food choice motives, food neophobia, consumer attitudes, consumer acceptance, sustainability

Introduction

Reducing meat consumption could help to protect the natural environment, and lower intake of red and processed meat is linked with reduced risks of numerous chronic conditions (1). Plant-based meat substitutes, such as those made of textured vegetable protein or mycoprotein, could enable meat eaters to replace meat

This study was funded by the Wellcome Trust, Our Planet Our Health program [Livestock, Environment, and People (LEAP), award number 205212/Z/16/Z]. FB's time on this project was funded by the Medical Research Council, Green Templeton College, and the NIHR School for Primary Care Research. NMA, PA and SAJ are supported by the NIHR Oxford Biomedical Research Centre. PA and SAJ are also supported by the NIHR Applied Research Collaboration and are NIHR senior investigators.

Supplemental Tables 1 and 2 are available from the "Supplementary data" link in the online posting of the article and from the same link in the online table of contents at https://academic.oup.com/ajcn/.

Address correspondence to BC (e-mail: brian.cook@phc.ox.ac.uk).

Abbreviations used: BOCF, baseline observation carried forward; GHG, greenhouse gas; RCT, randomized controlled trial; RE-MAP, replacing meat with alternative plant-based products.

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First published online December 27, 2021; doi: https://doi.org/10.1093/ajcn/nqab414.





Source: Bianchi F, Stewart C, Astbury NM, Cook B, Aveyard P, Jebb SA. Replacing meat with alternative plant-based products (RE-MAP): a randomized controlled trial of a multicomponent behavioral intervention to reduce meat consumption. Am J Clin Nutr. 2022 May 1;115(5):1357-1366. doi: 10.1093/ajcn/nqab414. PMID: 34958364; PMCID: PMC9071457.

**Number of participants:** 115 British adults who regularly ate meat.

**Study design:** Participants were randomised to receiving free plant-based meat and guidance on the environmental and health advantages of eating more plant-based foods for a period of 4 weeks, and after another 4 weeks were checked on to review behaviour change following the intervention. The control received no intervention or advice on dietary change.

**Outcomes examined:** The primary outcome was reduction in meat consumption per day, with secondary outcomes exploring whether changes persisted after the trial finished, and health **biomarkers** such as weight, cardiovascular risk factors and diet nutrient composition.

**Key findings:** Those in the plant-based meat arm ate an average of 63g less meat per day during the intervention and also experienced statistically significant weight loss of half a kilo. This brought consumption by those in the intervention group down from an excess of meat eaten at baseline (130g/day) to within the recommended daily amount (70g/day or less). At follow-up 4 weeks after the intervention finished, participants were still eating 39g less per day compared to baseline. No other significant changes were observed. No changes were seen in the control group at either time point.

# Research available to date* on UPF and its relevance to plant-based meat

**In this section:**

- Several features of datasets used in UPF research limit their relevance to plant-based meat:
  - Most rely on food diaries taken before Nova and most modern plant-based meat existed, and lack the detail needed to categorise newer foods like plant-based meat.
  - Plant-based meat makes up a tiny proportion of UPF eaten, and other UPF foods probably drove observed outcomes.
- **Experimental trials** (Hall *et al* 2019, Hamano *et al* 2024) suggest high **caloric density** and low fibre content (which don't apply to plant-based meat) are at least partially behind the health impacts of high-UPF diets.
- Publicly funded bodies in France, Germany, Spain, and the UK (ANSES 2025, DGE 2023, Aesan 2020, SACN 2025) have independently found insufficient evidence to support policies targeting UPFs that have a good nutritional profile.
- There are large discrepancies between the findings of research to date and the high volume of poor quality media reporting on the topic.

*As of 20 May 2025

# Topic: Research to date on UPFs and its relevance to plant-based meat

| Statement | Further detail |
| --- | --- |
| Most of the findings to date come from **observational** (or 'real-world') studies, and focus on patterns at the population level. | ● It can be a challenge to tease out the long-term impacts of specific foods and different dietary patterns because the kinds of diseases associated with poor diet tend to take years to develop.<br>● Real-world evidence, which tracks data from people going about their daily lives over long periods of time, is therefore often used to research dietary patterns, and comprises most UPF studies to date.<br>● These studies show groups of people who eat the most UPF, and the least minimally processed food, are more likely to develop a number of negative health outcomes, from heart disease to cancer to depression.<br>● However, this data can only tell us about dietary patterns, not individual foods, limiting relevance to plant-based meat:<br>○ Because most UPFs are high in calories, salt, fat and sugar, and low in nutrients and fibre, these studies ar at risk of **confounding**, and cannot tell us how much of the health impacts are caused by processing, and how much by these nutritional features we already know negatively impact health.<br>○ Plant-based meat, which generally has a good nutritional profile, makes up only 0.2% of calories eaten in datasets like UK Biobank (Rauber *et al* 2024), meaning findings on UPFs overall are unlikely to apply.<br>○ Population-level data is less able to explore specific questions in smaller, non-standard groups. Plant-based meat does not contribute a significant proportion of calories in average high UPF diets, and UK Biobank data suggests those who eat the most plant-based meat generally follow non-standard dietary patterns such as pescetarian or vegetarian (suppl material. Chang *et al* 2024). Those following these diets in the UK Biobank dataset generally had lower risk of cancer (Parra-Soto *et al* 2022) and **cardiovascular disease** (Petermann-Rocha *et al* 2021), unlike those eating the most UPF generally.<br>○ To prove what is causing the observed outcomes and separate out these factors, studies using other designs such as randomized-controlled trials (RCTs) would be needed.<br>● This is a challenge because RCTs are more expensive and take longer to conduct, while the harms of poor diet are pressing, and people are very interested in any research they think can help them improve their health. |

# Topic: Most commonly used datasets for UPF studies

| Statement | Further detail |
| --- | --- |
| What datasets are used in real-world UPF studies? | • Many of the landmark UPF studies to date are based on datasets from large health mapping projects set up to monitor trends in key health metrics over long periods of time.Three major European examples of these datasets include:<br>  ○ **The EPIC cancer database.**<br>  ■ A database following over half a million enrollees in 10 European countries, started in the 1990s.<br>  ■ At enrollment, each person completed in-depth health questionnaires, including on diet, lifestyle and other factors like health status, medications and basic measurements.<br>  ■ Follow-up was then conducted at varying points to measure changes over time.<br>  ○ **The Navarra SUN study.**<br>  ■ A Spanish database started in 1999 to explore the nutritional benefits of the Mediterranean diet, which now has over 20,000 enrollees, mostly alumni from the University of Navarra.<br>  ■ Anyone can register, after which they complete a baseline questionnaire covering food frequency, health status, medicine usage and lifestyle.<br>  ■ A shorter follow-up questionnaire is then taken every two years to track changes over time.<br>  ○ **The UK Biobank**<br>  ■ This is the largest biomedical database in the world, founded in 2006, with over half a million UK adults enrolled.<br>  ■ Anonymised information on genomes and electronic health records are collected alongside the baseline questionnaires.<br>  ■ Additional smaller groups of participants have also contributed other information like body, brain and heart scans, activity data from wearables, and questionnaires on behaviour, diet, mental health and pain management.<br>• Other commonly used datasets from outside Europe include the US NHANES database and Nurses Health Study. |

# Topic: Available research into UPF and health

| Statement | Further detail |
| --- | --- |
| What are the challenges of using these datasets to explore UPF in relation to plant-based meat? | • Certain limitations of these datasets make it particularly difficult to use them to assess plant-based meat:<br>  ○ **The food intake data predates Nova, and so lacks granular detail essential for categorisation.**<br>  ■ In food frequency questionnaires used by these databases, 'meat alternatives', if recorded at all, were not grouped by processing level making it impossible to separate traditional products like tofu (Nova 3) from plant-based meat (Nova 4) (Riboli *et al* 2003 (EPIC), Oxford WebQ (Biobank)).<br>  ■ Few people know much about how plant-based meat is made – including UPF researchers. Plain **mycoprotein**-based products made using biomass fermentation and freezing would generally fall in Nova 3, and yet they are typically assumed to be made with extrusion and placed in Nova 4.<br>  ○ **Food intake data is usually from before many modern plant-based meat options existed.**<br>  ■ Studies are looking for changes over long time periods, so most UPF studies use the baseline food frequency questionnaires to map UPF intake.<br>  ■ This means in studies using the EPIC cohort, UPF intake data is at least 25 years old (Dicken *et al* 2024), and in those using the UK Biobank it is at least 10 years old (Chang *et al* 2023). While some plant-based meat products do predate this, the large expansion of plant-based meat as a category began around 2019, long after any of these data were collected.<br>  ○ **The people in these studies get a vanishingly small proportion of their calories from plant-based meat, making it impossible to separate the impact of plant-based meat from more commonly eaten UPFs.**<br>  ■ In the Biobank dataset, just 0.2% of calories came from 'plant-based alternatives to meat', which also included tofu (suppl material. Rauber *et al* 2024). By comparison, 16% were from sweet snacks and drinks like pastries, cakes, biscuits, soft drinks and confectionery, and 9% were from UPF animal sourced foods like milkshakes, processed meat and dairy-based puddings (Rauber *et al* 2024).<br>  ■ Several of these larger UPF groups are independently associated with negative health outcomes (Nguyen *et al* 2022, Feng *et al* 2021). |

# The average increased risk of developing cardiovascular disease, coronary heart disease or stroke for those with diets high in UPF as a whole (light blue), and those with diets high in UPF excluding processed meat and sugary drinks (dark blue)

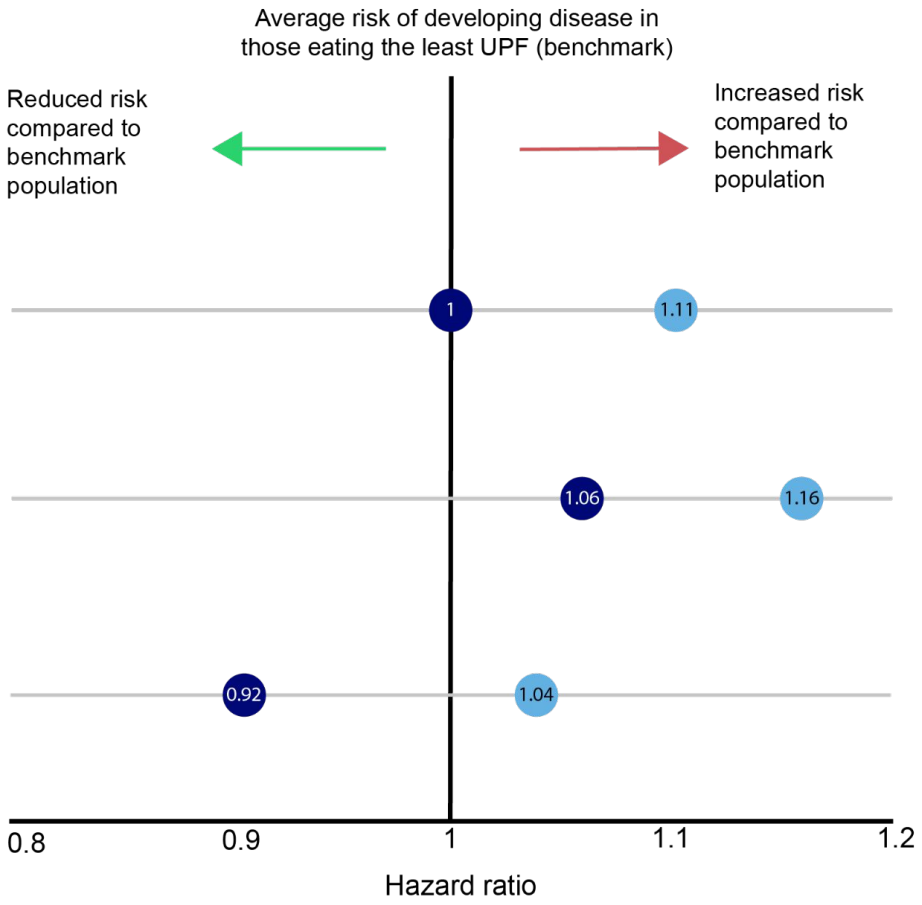
Associated risk for high intake of all UPF

Associated risk for high intake of UPF excluding UPF processed meat and sugary drinks

**Cardiovascular disease**
Risk increase in those eating the most UPF was driven by sugary drinks and processed meat. With the influence of these subgroups removed those eating the most and the least UPF had the same CVD risk.

**Coronary heart disease**
Most of the risk increase in those eating the most UPF was driven by sugary drinks and processed meat subgroups.

**Stroke**
Processed meat and sugary drinks drove the small increased risk of stroke in those eating the most UPF. UPF intake was unlikely to be a major factor in stroke risk as with these subgroups removed those eating the most UPF had a lower incidence of stroke than those eating the least.




"The diverse nutritional composition within these products warrants the need to deconstruct the ultra-processed food classification for a nuanced understanding of their impact on cardiovascular health. **Our findings suggest that soft drinks and processed meats should be particularly discouraged,** given their consistent adverse association with cardiovascular disease, coronary heart disease, and stroke."

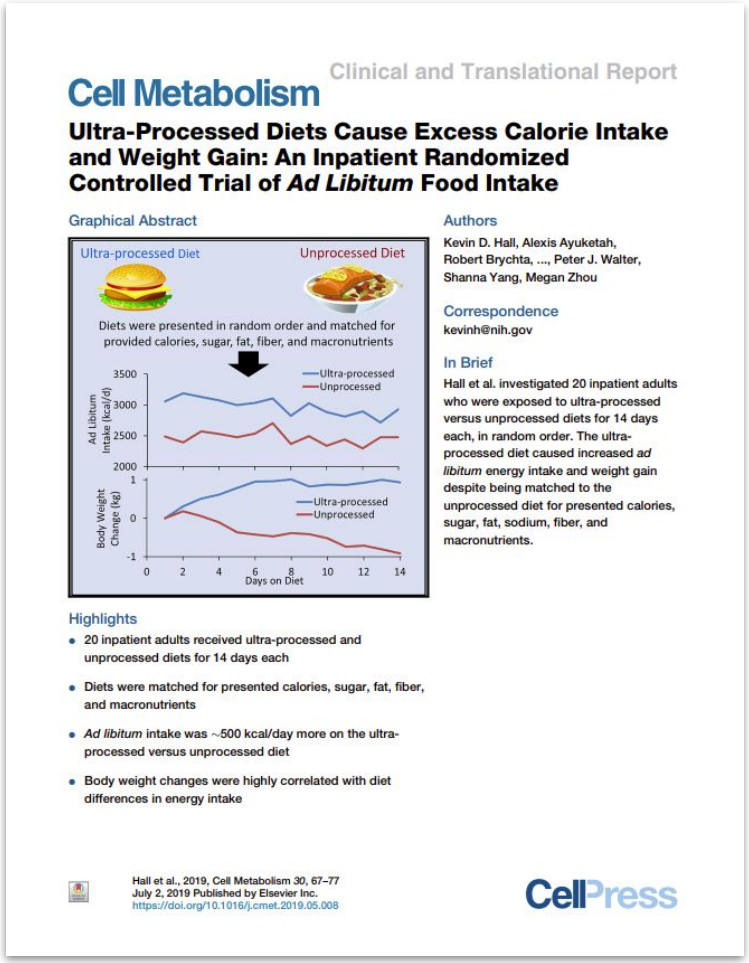
Reproduction using data from: Mendoza, Kenny et al. Ultra-processed foods and cardiovascular disease: analysis of three large US prospective cohorts and a systematic review and meta-analysis of prospective cohort studies, *The Lancet Regional Health – Americas*, 2024, Volume 37, 100859

# Topic: Available research into UPF and health

| Statement | Further detail |
| --- | --- |
| Real world studies have found that different kinds of UPF have different associated health risks, with sugary drinks and processed meat being the two subgroups most strongly associated with harm. | • Studies breaking down ultra-processed foods by sub-category have found that processed meat, savoury snacks and sugary drinks drove a significant proportion of the adverse health associations with UPF, with processing levels in other subgroups seeming to have far weaker, if any, negative links (Cordova *et al* 2024, Dicken *et al* 2024).<br>• A systematic review of several trials, which normalised UPF intake to remove the influence of foods already linked with increased risk on the category as a whole, found that with processed meat and sugary drinks removed, the risk associations with **cardiovascular disease** and stroke disappeared (Mendoza *et al* 2024*, see page 30*). Another looking at diabetes found that processing level had far weaker risk associations than specific food groups like processed meat and sugary drinks taken individually (Mendoza et al 2025).<br>• This suggests that while the **epidemiological** lens of viewing Nova may hold, more nuance is likely needed when using it to profile individual foods – particularly those with generally favourable nutritional profiles like plant-based meat. |
| Two interventional trials have been completed, and a partial readout from a third has been released to date (March 2025). All three suggest that nutritional characteristics of these foods do factor into the health impacts of UPF. | • While there are many real-world studies, many are based on the same people in the same 5-6 datasets (*see page 28*) and have very similar methodologies and research questions. This makes it very important to see the results from new studies using a wider variety of study designs to gain a deeper understanding – particularly RCTs.<br>• Several randomised controlled trials are underway seeking to test whether the associations between UPF consumption and negative health outcomes are still seen when normalising for factors such as nutrient composition, and to date two have been published (Hall *et al* 2019, Hamano *et al* 2024 *see pages 32 and 33)*.<br>• These preliminary data have teased out more detail on what specifically about UPF may drive the patterns seen in real world studies, highlighting certain specific aspects of processing that may be driving increased health risks:<br>  ○ The higher **caloric density** of diets high in UPF (ie number of calories per 100g).<br>  ○ The **hyper-palatability** and softer texture of many UPF foods, encouraging excess consumption.<br>  ○ The lower fibre content of high UPF diets, and the type and format of fibre (ie in food or as a drink supplement).<br>• These trials are still small and only cover very short time periods, but they suggest UPF's health impacts are at least in part due to nutritional factors like **caloric density** and fibre content – both of which plant-based meat performs well on. |

# **Summary:** Hall et al, 2019 – the first randomised controlled trial on UPF





Cell Metabolism

Clinical and Translational Report

**Ultra-Processed Diets Cause Excess Calorie Intake and Weight Gain: An Inpatient Randomized Controlled Trial of *Ad Libitum* Food Intake**

Graphical Abstract



Authors

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In Brief

Hall et al. investigated 20 inpatient adults who were exposed to ultra-processed versus unprocessed diets for 14 days each, in random order. The ultra-processed diet caused increased *ad libitum* energy intake and weight gain despite being matched to the unprocessed diet for presented calories, sugar, fat, sodium, fiber, and macronutrients.

Highlights

- 20 inpatient adults received ultra-processed and unprocessed diets for 14 days each
- Diets were matched for presented calories, sugar, fat, fiber, and macronutrients
- *Ad libitum* intake was ~500 kcal/day more on the ultra-processed versus unprocessed diet
- Body weight changes were highly correlated with diet differences in energy intake

Hall et al., 2019, Cell Metabolism *30*, 67–77
July 2, 2019 Published by Elsevier Inc.
https://doi.org/10.1016/j.cmet.2019.05.008

CellPress

**Number of participants:** 20

**Study design:** 20 healthy American participants were randomised to either UPF or non-UPF based diets for 14 days. Once complete, there was a break and the two groups swapped for another 14 days, so both tried both the UPF and non-UPF menu. The meals themselves were matched for calories and macronutrients (although distribution throughout the meal varied), but all were far larger than a single portion, so participants would eat until they were full.

**Was plant-based meat included?** No

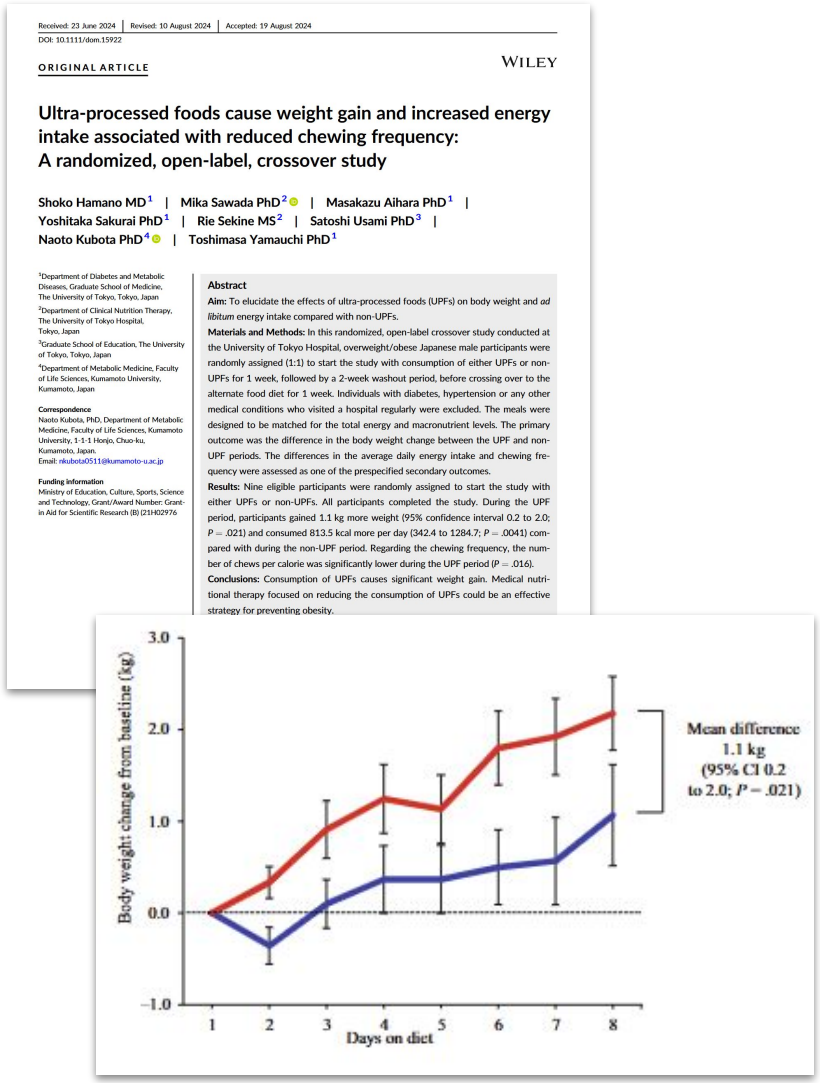
**Outcomes examined:** The primary outcome explored was differences in daily calorie intake, with change in body weight from baseline, change in body fat mass, perceived food pleasantness, eating speed and satiety as secondary outcomes.

**Key findings:** "Energy intake was greater during the ultra-processed diet, with increased consumption of carbohydrate and fat, but not protein. **Weight changes were highly correlated with energy intake**, with participants gaining 0.9 ± 0.3 kg during the ultra-processed diet and losing 0.9 ± 0.3 kg during the unprocessed diet." No differences were found in participant ratings of food pleasantness, eating speed, liver fat, or fullness. Body fat measures were inconclusive, with gains in both fat mass and fat-free mass in the UPF diet and losses of both in the non-UPF diet.

Source: Hall et al., 2019, Cell Metabolism 30, 67–77 July 2, 2019. doi.org/10.1016/j.cmet.2019.05.008

# **Summary:** Hamano et al, 2024 – the second published RCT on UPF





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ORIGINAL ARTICLE

WILEY

**Ultra-processed foods cause weight gain and increased energy intake associated with reduced chewing frequency: A randomized, open-label, crossover study**

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**Abstract**

**Aim:** To elucidate the effects of ultra-processed foods (UPFs) on body weight and *ad libitum* energy intake compared with non-UPFs.

**Materials and Methods:** In this randomized, open-label crossover study conducted at the University of Tokyo Hospital, overweight/obese Japanese male participants were randomly assigned (1:1) to start the study with consumption of either UPFs or non-UPFs for 1 week, followed by a 2-week washout period, before crossing over to the alternate food diet for 1 week. Individuals with diabetes, hypertension or any other medical conditions who visited a hospital regularly were excluded. The meals were designed to be matched for the total energy and macronutrient levels. The primary outcome was the difference in the body weight change between the UPF and non-UPF periods. The differences in the average daily energy intake and chewing frequency were assessed as one of the prespecified secondary outcomes.

**Results:** Nine eligible participants were randomly assigned to start the study with either UPFs or non-UPFs. All participants completed the study. During the UPF period, participants gained 1.1 kg more weight (95% confidence interval 0.2 to 2.0; $P = .021$) and consumed 813.5 kcal more per day (342.4 to 1284.7; $P = .0041$) compared with during the non-UPF period. Regarding the chewing frequency, the number of chews per calorie was significantly lower during the UPF period ($P = .016$).

**Conclusions:** Consumption of UPFs causes significant weight gain. Medical nutritional therapy focused on reducing the consumption of UPFs could be an effective strategy for preventing obesity.




**Number of participants:** 9

**Study design:** Nine overweight Japanese male participants were randomised to either UPF or non-UPF based diets for seven days. Once complete, there was a break and the two groups swapped for another seven days, so both tried both the UPF and non-UPF menu. The meals themselves were matched for calories and macronutrients (although distribution throughout the meal varied), but all were far larger than a single portion, so participants would eat until they were full.

**Was plant-based meat included?** No

**Outcomes examined:** The primary outcome explored was changes in body weight, with daily average energy intake and chewing frequency as secondary outcomes.

**Key findings:** Unlike in the Hall study, weight gain was observed in both the UPF and non-UPF arms, however during the UPF period, **participants gained 1.1 kg more weight and consumed 813.5 kcal more per day compared with during the non-UPF period**. Regarding the chewing frequency, the number of chews per calorie was significantly lower during the UPF period.

Source: Hamano S, et al. Ultra-processed foods cause weight gain and increased energy intake associated with reduced chewing frequency: A randomized, open-label, crossover study. Diabetes Obes Metab. 2024 Nov;26(11):5431-5443. doi: 10.1111/dom.15922. Epub 2024 Sep 12. PMID: 39267249.

# Topic: Available research into UPF and health

| Statement | Further detail |
| --- | --- |
| Several national health bodies have found that there is no sufficient evidence to warrant policy interventions on the basis of Nova category alone, recommending that, if used, it is combined with other complementary factors that account for nutritional profile. | • Many European governments agree on the need to address the growing problems linked to poor diets. However, independent, publicly funded investigations from multiple European countries all agree that the evidence is not strong enough to recommend policy or public health education based on processing level alone:<br>  ○ France's ANSES report, published in January 2025.<br>  ○ Germany's DGE systematic review, published December 2023.<br>  ○ The UK's SACN report, published in July 2023 and updated in April 2025, and the UK House of Lords report on Food, Diet and Obesity, published October 2024.<br>  ○ Spain's Aesan report, published in 2020.<br>  ○ The 2023 Nordic Nutrition recommendations also do not recommend use of UPF over existing frameworks.<br>• However, the general public remains confused by the seeming disconnect between these conclusions and the high volume of news stories on the topic, and what the findings mean in practice.<br>• Better communication on this topic is sorely needed to help people make better food choices. |
| The research to date is unlikely to tell us much about plant-based meat. | • It is clear that the narrative surrounding UPF has given many people a misleading impression of the nutritional profile of plant-based meat, even though there is good evidence it could be a helpful tool to support healthier and more sustainable choices.<br>• Foods like processed meat, which plant-based meat is designed to replace, appear to play a large role in driving increased health risks associated with UPFs.<br>• Making processed foods healthier is likely a key part of effectively improving diet-related ill health on a population level. In parallel, another key component lies in making healthy whole foods like vegetables, legumes and beans more accessible and affordable. These two strategies likely complement one another. |

# Summary, conclusions and recommendations

# Summary

**Plant-based meat makes up a vanishingly small proportion of food eaten in both epidemiological studies and RCTs on UPFs, and also has a very different nutritional profile to most UPFs. It is therefore unlikely this research can tell us much about plant-based meat's health impacts.**

- In the UK Biobank dataset, plant-based meat made up just 0.2% of calories eaten (Rauber et al 2024).
- Most UPFs are high in fat, sugar, salt and **caloric density**, and low in fibre. **Caloric density** and low fibre content have been identified as the most likely mechanisms for health impacts seen in existing RCTs looking at UPFs. On average, plant-based meat is not high in fat, sugar or salt, is a source of fibre, and does not have high **caloric density**. This suggests studies on the UPF group as a whole likely offer little insight into plant-based meat, and will likely be misleading as to its health impacts.
- RCTs exploring the effects of plant-based meat as a replacement for conventional meat have generally found positive effects, which are in line with what we would expect based on their nutritional profile, in particular their fibre content and fat profile. These RCTs are better quality evidence.

**There is room for improvement in the nutritional profile of plant-based meat, particularly more consistent fortification and reduction of nutrients of concern such as salt.**

- A lot of variation currently exists in the nutritional profile of plant-based meat available in Europe. In particular, rates of **fortification** are currently inconsistent, although they are improving over time. Salt content is currently moderate, and most people could benefit from reducing salt intake.
- The best available evidence nevertheless suggests that replacing processed meat with plant-based versions could have medically relevant health benefits, most notably reductions in LDL cholesterol.

**People are currently eating more than recommended daily intakes of meat, and more options to help reduce this has several public health advantages.**

- There is good evidence linking over-consumption of processed meat with higher risk of colorectal cancer, the second leading cause of cancer death in Europe. The negative impact of processed meat is also highlighted by UPF studies.
- Publicly funded research to make tasty, affordable plant-based meat options that can out-compete the conventional products driving this over consumption may help support adherence to healthier, more sustainable diets.
- This would have broader public health benefits, such as reducing the risks of emergent zoonotic diseases and antimicrobial resistance, both of which are exacerbated by modern intensive farming practices (Kelbrick *et al* 2023, Hayek 2022).

# Conclusions

Research on ultra-processed foods has broadened the **epidemiological** understanding of diet-related ill health, and unlocked political will to drive much-needed change in our food system.

Plant-based meat is an accessible option with particular opportunities as a replacement for processed meat – which has been identified by research into UPF as one of the subcategories most strongly associated with increased health risks.

Although trials have identified several key features of UPFs as a whole that are likely to play a large role in the negative outcomes observed (high **calorie density**, low fibre and **hyper-palatability**); plant-based meat has a very different nutritional profile from most UPFs, and these metrics do not generally apply to plant-based meat.

With current meat consumption in Europe above recommendations for both public and planetary health, a diverse range of strategies are likely required to support the necessary increase in consumption of plant-based foods. There is no single path to achieving this, and multiple complementary strategies are likely needed. Support for tasty, affordable plant-based meat and encouraging greater uptake of whole plant foods are two such strategies, and each likely has differing appeal to different demographic groups.

**On this basis, proponents of the Nova framework and of protein diversification should be incentivised to identify where each can have the most impact building a healthier, more sustainable food system, and collaborate to target their work accordingly.**

# Recommendations

## Public health and nutrition professionals should challenge misconceptions on processing and plant-based meat.

- UPF research is poorly understood by the general public, and misconceptions are common.
- This is compounded by limited familiarity with plant-based meat and its nutritional profile, with many assuming it is high in salt, sugar and fat like the majority of UPF.
- Better communication on these points to improve accuracy and reduce sensationalism is sorely needed.
- Greater emphasis should be placed on the fact that there are multiple pathways to healthier lifestyles – and the most effective interventions are those that can be adhered to.

## Researchers should focus on diversifying the evidence base for UPF and plant-based meat.

- Interventional studies (eg randomised controlled trials) are needed to understand what features of UPF drive harm, and how to effectively address the impacts of the most harmful foods.
- Such studies are also needed to explore which qualities of plant-based meat are behind observed beneficial outcomes to help guide further improvements.
- Behavioural research is needed to understand the best levers to achieve widespread dietary improvement, and how to effectively target the groups most affected by diet-related ill health.
- Food diaries and food frequency questionnaires used in nutritional **epidemiology** should be designed to capture plant-based meat consumption.

## National bodies should create guidelines to help people select healthier options, and increase consistency across products.

- This includes guidelines on features like **fortification**, fibre and salt, where variation across plant-based meat products exists.
- Products meeting these positive thresholds should also be included in national dietary guidance, as is the case in the Netherlands.
- Guidelines that support more accessible pathways to healthy dietary patterns should also be explored.

# Learn more about plant-based meat and health


# Appendix

# **A1:** common processes used for high-protein plant-based foods

## Protein base

Lower

**Processing level**

Higher

Biomass fermentation. Used for plant-based meat. Certain kinds of fungi that grow small fibres – called filamentous fungi – are grown in a fermenter. They are then siphoned off and warmed before being separated from the water, giving a minimally processed ingredient high in **soluble fibre** and **complete protein** (Quorn, 2017).

**Wheat flours.** Used for **seitan**. Wheat flour is made into a dough then washed, leaving the protein behind. While the protein concentration is high, it is not complete, and much of the fibre is removed.

**Soy curds.** Used for tofu. Dried soybeans are soaked, blended and cooked. The resulting soy milk is separated from the fibre pulp. A **coagulant** is then added to curdle the milk. This works by changing the pH to match its **isoelectric point,** causing the protein to **precipitate** into curds (like in cheesemaking). These solid curds are then removed and pressed. These have complete protein and while some fibre is lost, more is kept than in **seitan**.

**Concentrates and isolates.** Used for plant-based meat. Several methods can be used to separate protein from other constituents in raw plant ingredients (**fractionation**), resulting in different nutritional characteristics. **Concentrates** retain more of the original **food matrix**, including fiber and beneficial plant compounds like polyphenols, while **isolates** are nearly pure protein. Two main methods are used:

- **Dry fractionation** (used to make **concentrates**) separates protein by particle size and weight. First, the raw ingredient is dried and milled. During milling, protein-rich particles tend to be smaller than those containing more starch or fiber. Air is then used to separate these smaller, protein-dense particles from the larger starch- or fiber-rich ones, forming the concentrate. This method is energy-efficient and produces fewer byproducts, but is usually lower in protein and harder to texturise.

- **Wet fractionation** (used to make **concentrates** and **isolates**) separates protein based on solubility. The raw ingredient is ground into a meal and, for oil-rich sources like soybeans and chickpeas, defatted. If already a liquid, the pH can be changed to precipitate the protein curd out of solution**.** If not, the protein is first dissolved using alkaline agents. The resulting protein solution is then extracted, and precipitated into a curd as in the other processes. This curd is then washed, filtered or centrifuged, and dried to produce a powdered **isolate** with over 90% protein content.

**Mixing with other ingredients**

See slide 9 for more information on other commonly used ingredients.

# **A2:** common processes used for high-protein plant-based foods

Lower

**Processing level**

Higher

## Texturisation

**Solid state fermentation [new technology not yet used at large scale].** Fermentation conditions are optimised to cultivate **mycelium** from certain edible fungi species to produce a denser, more meat-like texture than normal growth patterns.

**Pressing/moulding.** Ingredients are combined and pressed into shape. This approach involves little processing but limits the scope of achievable textures.

**3D printing.** Already used in other food applications (eg, intricate chocolate shapes). Different mixtures of ingredients are developed to replicate the composition of a piece of meat (eg, rind or breast) and put into a 3D printer and layered on top of one another. The level of processing here depends a lot on what is used to make the mixtures (or 'inks'). This makes it possible to create more realistic textures with ingredients made from algae and fungi that work poorly with extrusion, enabling the creation of more complex structures (eg, a flaky fish fillet).

**Extruding.** The most commonly used process today, extrusion has been used to make common foods such as shaped pasta and TVP for over 80 years. The ingredient mix is first cooked, and then forced through a high pressure nozzle. A range of different parameters like water use, pressure and temperature can be tweaked to change various characteristics of the end product like texture.

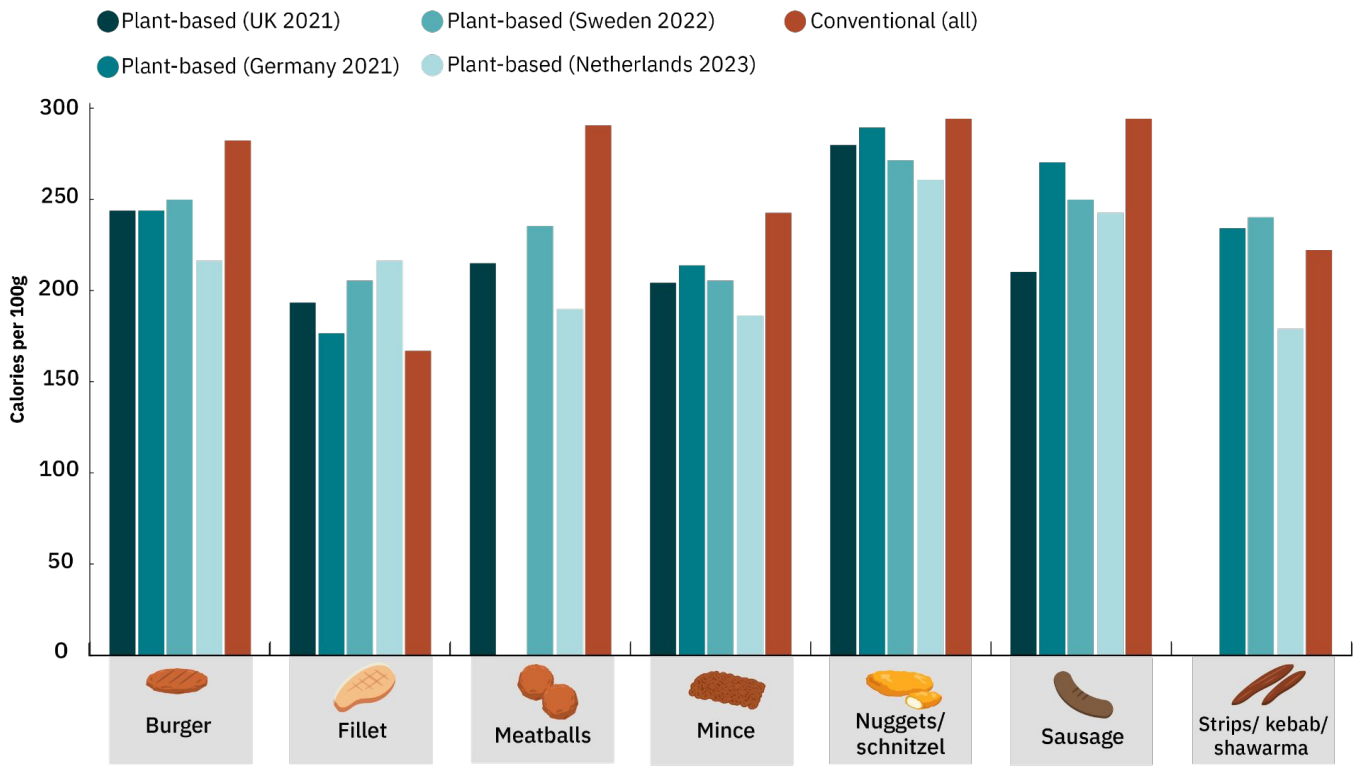
**Fibre spinning [new technology not yet used at large scale].** Plant protein is dissolved in a liquid, which is drawn through a spray head with several small holes into another solution that solidifies it – creating individual fibres analogous to those found in muscle. This is a approach gives much more granular control over the arrangement of the fibres in the end product, which can be used to achieve a more realistic muscle texture.

**End product**

# A3: calorie density in plant-based versus conventional meat

| Point | Further detail |
|---|---|
| Plant-based meat tends to have lower **calorie density**. | • Choosing foods with lower calories by weight can reduce overall calorie intake (Robinson, *et al* 2022).<br>• Randomised controlled trials exploring mechanisms for UPF impacts on health suggest their higher average **calorie density** is one of the primary drivers of observed weight gain (Hall *et al* 2019, Hamano *et al* 2024).<br>• Plant-based meat does not have a high **calorie density**, in contrast to many other UPFs.<br>• On average, plant-based meat products have similar or fewer calories per 100g than conventional meat. |

**Average calories per 100g in plant-based and conventional meat**

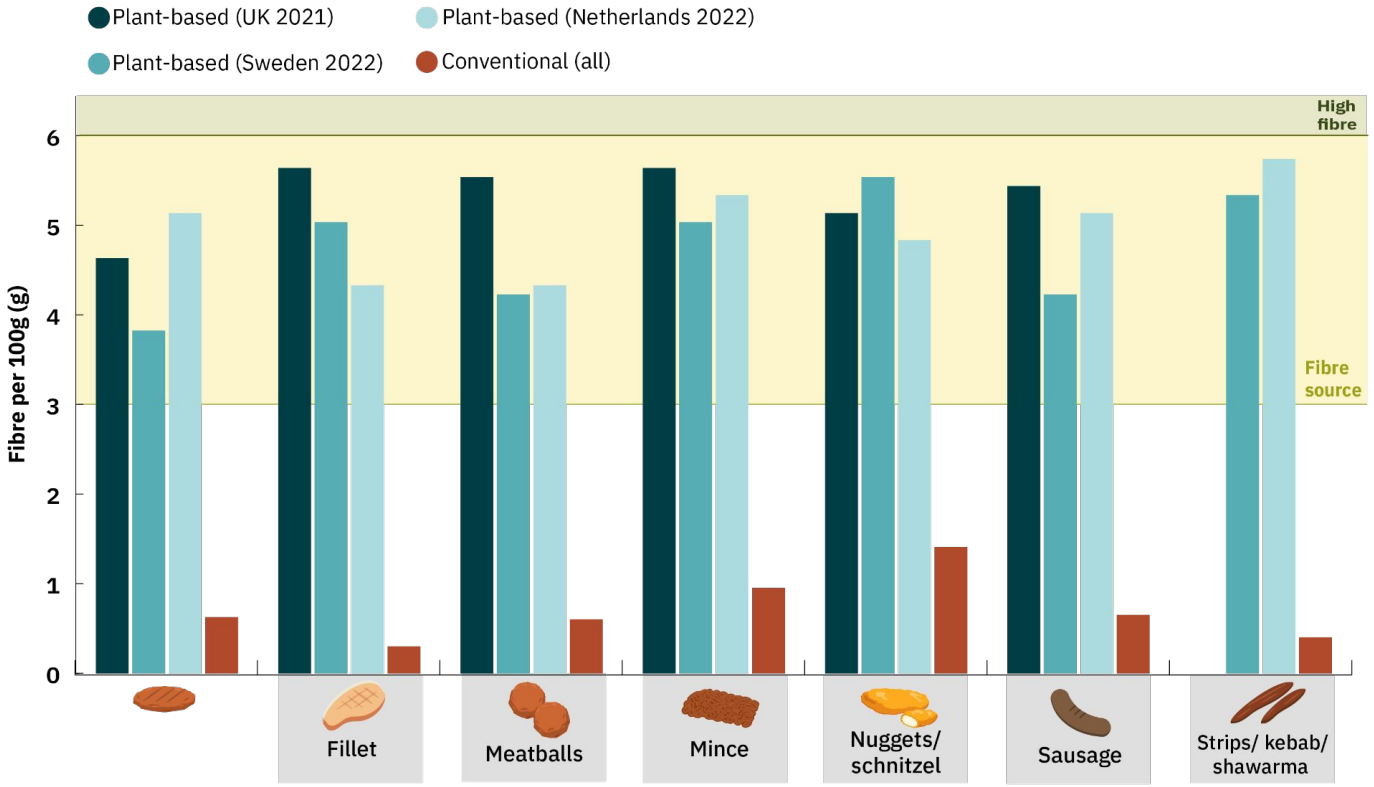



Reproduced from GFI Europe report, Plant-based meat and health (2023). Synthesis of median data from studies of nutritional composition of plant-based and conventional meat in Germany (Grea *et al* 2023), the Netherlands (van Haperen 2023), Spain (Heras-Delgado et al 2023), Sweden (Bryngelsson *et al* 2022) and the UK (Alessandrini et al 2021).

# A4: Fibre in plant-based versus conventional meat

| Point | Further detail |
|---|---|
| Plant-based meat tends to be a source of fibre | • There is growing evidence that high fibre intake helps maintain a healthy weight (Thompson *et al* 2017) and reduces **biomarkers** associated with **cardiovascular disease** (Hartley *et al* 2016,), echoed in studies of real world data (Threapleton *et al* 2013, Stephen *et al* 2017).<br>• Initial studies have also suggested fibre intake may influence gut and **microbiome** health (So *et al* 2018).<br>• Most Europeans do not eat enough fibre in their diet.<br>• Plant-based meat therefore offers an opportunity to increase fibre content in parts of meals that previously had none, with only minor tweaks to the recipe.<br>• Fibre content is another area where plant-based meat differs from average UPFs.<br>• Plant-based meat is a source of fibre. Conventional meat is not. |

**Average fibre per 100g in plant-based and conventional meat**

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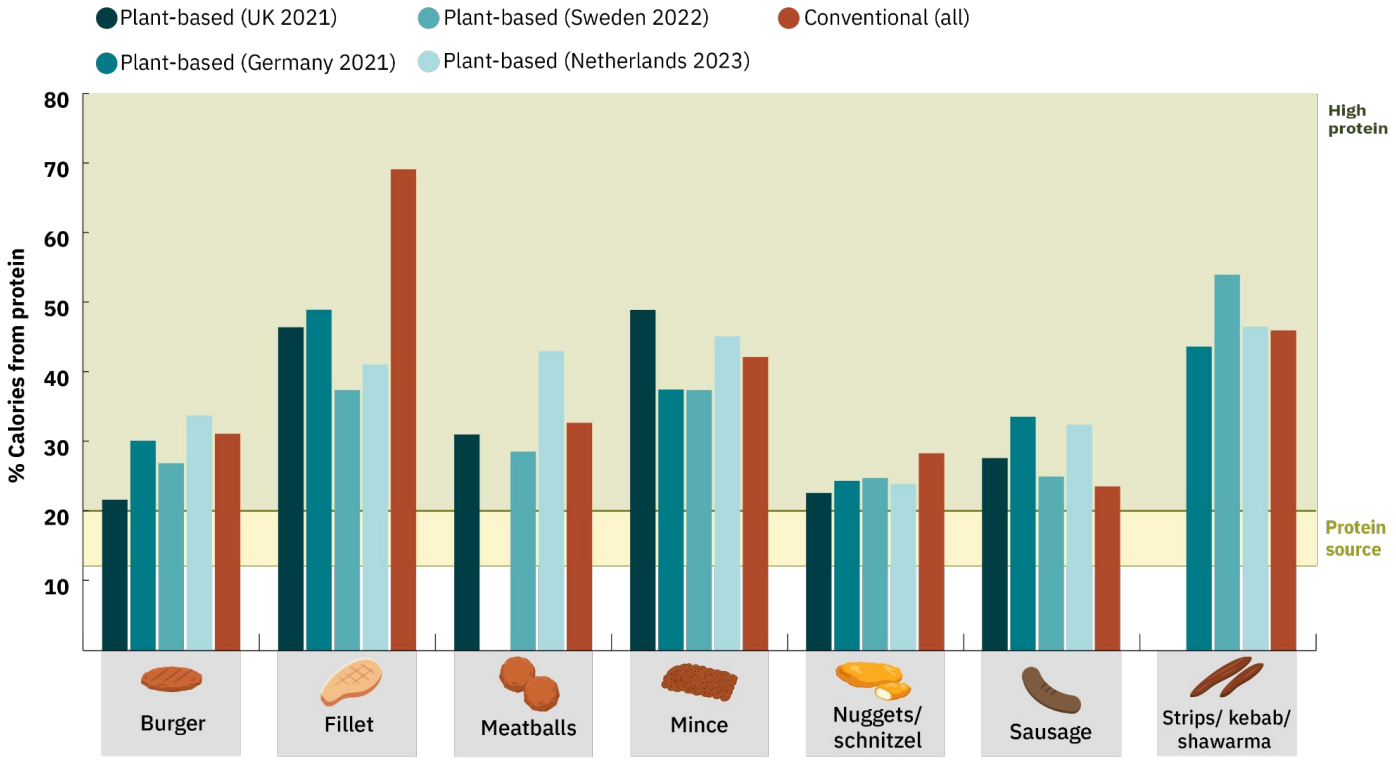
# A5: protein density in plant-based versus conventional meat

| Point | Further detail |
|---|---|
| Plant-based meat tends to be high in protein | • Plant-based meat comfortably meets the EU 'high protein' definition, with a percentage of calories from protein similar to that of conventional meat in most categories except lean fillets.<br>• The processing used to make plant-based meat can improve **protein density**, and **quality** relative to their raw ingredients (Manzanilla-Valdez *et al* 2024). More research to quantify specific impacts on these factors by processing method is needed.<br>• **Protein density** and **quality** are particular considerations for helping those with lower appetites (eg, older people), aiming for high protein intake within tight calorie thresholds (eg, athletes), or otherwise in **calorie deficit** (eg, trying to lose weight) maintain muscle mass (Domić *et al* 2025, Jäger *et al* 2017, Janssen *et al* 2023). |

**Average % of calories from protein in plant-based and conventional meat**

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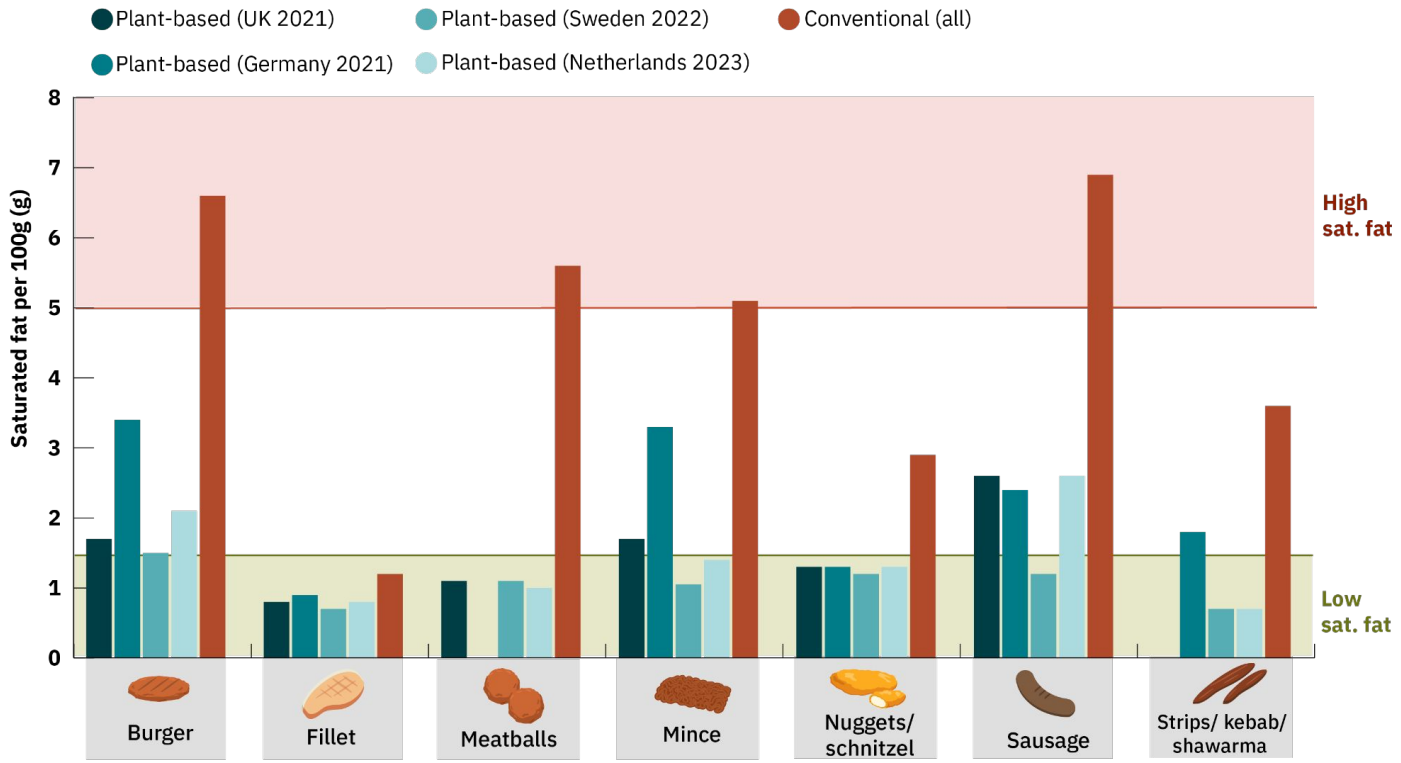
# A6: saturated fat in plant-based versus conventional meat

| Point | Further detail |
|---|---|
| Plant-based meat tends to be low in saturated fat | • There is good evidence that long-term reduction of saturated fat intake can reduce risk of cardiovascular events like heart attacks or strokes (Hooper *et al* 2020).<br>• Plant-based meat usually contains low levels of saturated fat, and significantly less than animal-based counterparts. |

**Average saturated fat per 100g in plant-based and conventional meat**

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# A7: sugar in plant-based versus conventional meat

| Point | Further detail |
|---|---|
| Plant-based meat tends to be low in sugar | • There is good evidence that high sugar consumption, particularly from sugar-sweetened drinks (Santos *et al* 2022), is associated with increased risk of **cardiovascular disease** and other chronic diseases (Huang *et al* 2023).<br>• Plant-based meat and conventional meat are both low in sugar.<br>• While both are 'low sugar' foods, in absolute terms plant-based meat contains slightly more.<br>• This is another key area where plant-based meat is significantly different from many of the most frequently consumed UPF food groups such as sugary drinks, cakes, biscuits and milkshakes. |

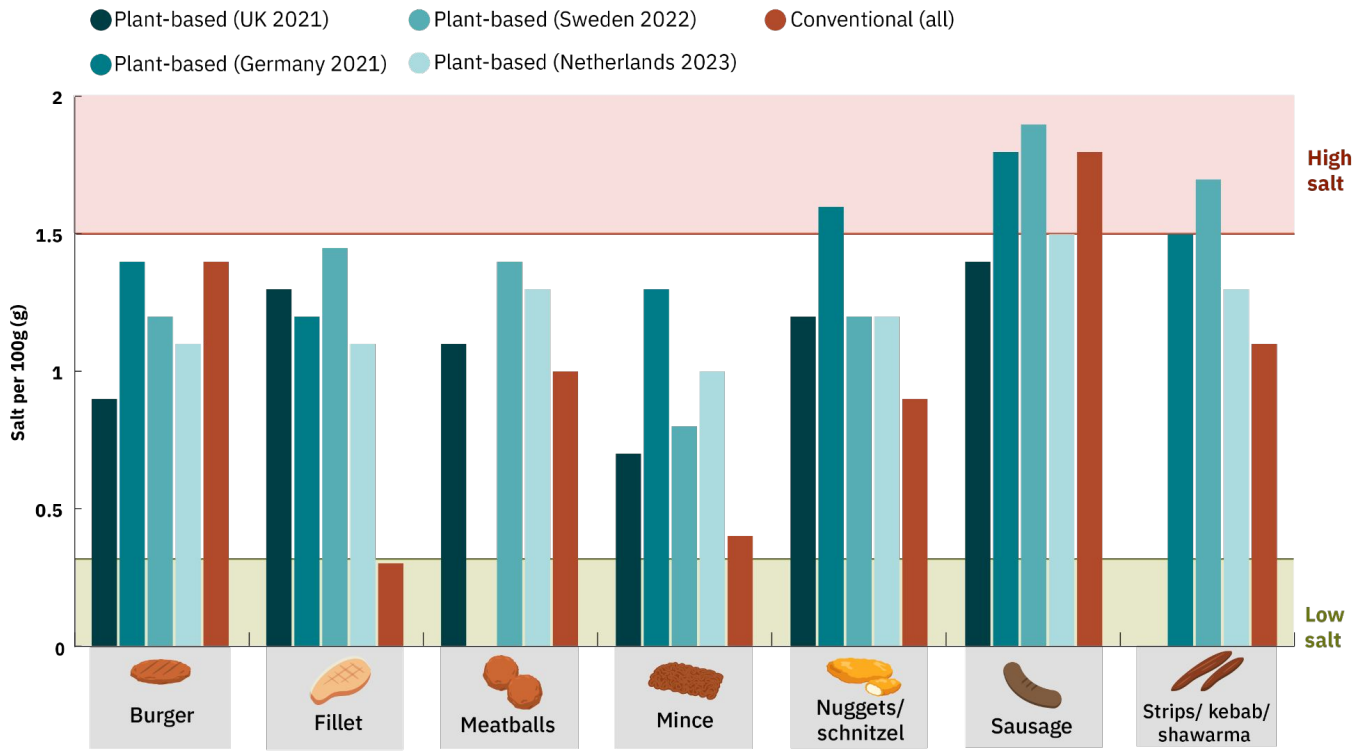
**Average sugar per 100g in plant-based and conventional meat**


Reproduced from GFI Europe report, Plant-based meat and health (2023). Synthesis of median data from studies of nutritional composition of plant-based and conventional meat in Germany (Grea *et al* 2023), the Netherlands (van Haperen 2023), Spain (Heras-Delgado et al 2023), Sweden (Bryngelsson *et al* 2022) and the UK (Alessandrini et al 2021).

# A8: salt in plant-based versus conventional meat

| Point | Further detail |
|---|---|
| Plant-based meat tends to have moderate salt content | • Most Europeans exceed the guideline maximum daily salt intake of 5-6g (2-2.4g sodium) (European Comission 2021, Kwong *et al* 2022).<br>• Excess salt intake is discouraged due to links with **high blood pressure**, which increases **cardiovascular disease** risk (Graudal *et al* 2020).<br>• Plant-based meat's salt content varies by country and product.<br>• Plant-based meat usually has moderate salt levels: more than unseasoned fresh meat but similar or less than processed meat (Espinosa et al 2024).<br>• A 2023 German study found plant-based salami had half the salt of conventional salami, but burgers were similarly salty (Grea et al 2023).<br>• RCTs replacing conventional meat with plant-based meat do not find any impact on blood pressure (Fernández-Rodríguez et al 2025). |

**Average salt per 100g in plant-based and conventional meat**

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# Glossary

**Artificial ingredients**
The EU does not have a legal definition for this term, but it is generally understood to mean ingredients that are synthesized, as opposed to being derived from a plant or animal.

**Bioavailability**
The proportion of a given nutrient in a food that the body can absorb for use in everyday functions.

**Biomarkers**
A biological molecule found in blood, other body fluids, or tissues that is a sign of a normal or abnormal process, or of a condition or disease.

**Calorie deficit**
A person is considered in calorie deficit when they use more energy than they gain from food, leading to weight loss as the body uses up energy stored as fat or muscle tissue to compensate.

**Calorie density**
Also known as energy density. Defined as the number of calories per 100g. The European Union does not have a formal definition of high calorie density, however 400 calories per 100g is a frequently used threshold for high calorie density (Nesta, 2024).

**Cardiovascular disease**
Medical conditions affecting the heart or blood vessels.

**Coagulant**
A compound or agent which is added to a liquid to thicken it.

**Concentrates**
Protein concentrates are ingredients used in plant-based meat that are typically made by milling the raw ingredients and separating out the most protein rich flour grains on the basis of their weight. Compared to isolates, they generally have a lower protein content, but retain more of the original food matrix, including fiber and beneficial plant compounds like polyphenols

**Confounding factors**
A confounding factor in a study is one that influences both the dependant variable and the independent variable, which if not accounted for can give the impression of an incorrect causal relationship between the two things being looked at. To give an example, a study might compare rates of ice cream consumption and incidence of sunburn in a given population, and see that people are more likely to get sunburned on days that they eat ice cream - ie that there is an association between these two variables. However, common sense tells us that eating ice cream does not cause sunburn. This is because of a confounding factor - sunny weather - which increases the rate of both ice cream consumption and sunburn. If we normalise the dataset to remove the influence of sunny weather (which we know independently causes sunburn) on the results, we would expect the association between eating icecream and sunburn to disappear.

**Diet quality**
Diet quality is a measure of how well someone's diet aligns with dietary guidelines. High quality diets are balanced and contain the right amount of energy, macro and micronutrients to support good health. There are several tools used to measure diet quality, such as the Healthy Eating Index (HEI).

**EFSA**
European Food Safety Authority - the EU's food safety regulatory body.

**Emulsifiers**
Emulsification is a general term referring to processes that allow a stable mixture of two or more liquids that would usually separate (eg oil and water). Emulsifiers facilitate this process. Ingredients with emulsifying properties have useful applications in food. Mayonaise is a widely used example of an emultion, using egg yolk as an emulsifier to combine oil and vinegar.

**Epidemiology**
The study of how often diseases occur in different groups of people and why. Epidemiological studies typically take large population-level datasets and look for patterns in those with higher rates of certain diseases to try and gain insight into the drivers of a given disease.

**Experimental trials**
Experimental trials, also known as interventional trials, are studies where researchers introduce a change in the study population to see how it affects an outcome. The most robust interventional study design is a randomised controlled trial (RCT).

**Food matrix**
The food matrix is the term used to describe the structure, composition and nutrient balance of a whole food. These structures can result in different biological responses compared to processed versions of the same food. For example, sugars in fruit are absorbed by the body at different rates depending on whether the fruit is being eaten whole or has first been blended into juice, or whether the fruit is raw or cooked.

**Fortification**
Fortification is when specific nutrients (often those identified as a risk of shortfall in the general population) are added to foods to help make it easier for people to get all the nutrients they need from their diet. Fortification of certain staples like bread are legally mandated in several European countries to support public health.

**Fractionation / fractioning**
Fractionation is a general term referring to any process that can split out the component parts of a mixture on the basis of their physical properties. For instance, using a centrifuge to separate by weight, or heating to separate by boiling point).

**Haem**
An iron-containing molecule present in blood cells which is used by the body to transport oxygen around the body. If eaten directly, haem iron is more easily used by the body than non-haem iron.

**Health claims**
Health claims are regulated terminology that can can be used to describe beneficial nutritional properties of given foods, provided they meet certain thresholds. These can be positive thresholds for beneficial nutrients (eg high fibre) or upper limits for nutrients harmful in excess (eg low sugar).

**High blood pressure**
High blood pressure (also known as hypertension) is a condition where the force of a persons blood as it pumped around the body is consistently high for an extended period of time. Over time, this can cause damage to the blood vessels (particularly small ones like those in the kidneys and eyes), and is linked to various health problems.

**Hyper-palatability**
This is not a standardised term, but generally refers to the relative ratios of fat, sugar, and salt in a given food item. Foods meeting a certain threshold of two or more of these macronutrients by weight are considered hyper-palatable. It has been suggested that such combinations make foods 'extra delicious' and consequently easier to over-eat.

**Hydrogenated oils**
Hydrogenated oils are saturated fats that have been fully converted from unsaturated fats using hydrogen, making them solid at room temperature. While saturated fats should not be eaten in excess, they are not to be confused with partially-hydrogenated fats, or artificial ‘trans-fats,’ which used to be used in some foods like baked goods and margarine. Trans fats are also naturally found in small amounts in red and processed meat. Artificial trans fats are strictly regulated and effectively or completely banned altogether in many countries.

**Isoelectric point**
The pH at which a molecule, especially a protein or amino acid, has no net electrical charge. The isoelectric point of a protein affects its solubility, and changing the pH to match this point causes it to come out of solution.

**Isolates**
Protein isolates are ingredients with a very high protein content, typically made using wet fractionation, which splits out the component molecules in plants based on their different solubility. They typically have higher protein content than concentrates, but less of the original food matrix.

**LDL (bad) cholesterol**
LDL cholesterol, or low-density lipoprotein cholesterol, is sometimes called bad cholesterol because it can build up inside a person's arteries, causing them to harden and narrow (a process called atherosclerosis), limiting blood flow. This can ultimately lead to a heart attack or stroke.

**Lectins**
Lectins are proteins that bind to carbohydrates, they perform a number of biological roles in the cells of living organisms. There are many different types of lectins, some of which are beneficial for health, while others can be harmful. Some lectins found in particularly high concentrations in legumes and grains have anti-nutritional properties, meaning these foods must undergo processing such as heating or fermenting to make them edible. Some lectins can also limit the body's ability to absorb certain micronutrients like iron and zinc, but again processing can be used to reduce or neutralise this effect. Research is still ongoing to fully understand the various ways in which different kinds of lechtin can have positive and negative interactions with various functions within the body.

**Limiting amino acids**
The essential amino acid found in the shortest supply relative to the amounts needed for protein synthesis in the body. Four amino acids are most likely to be limiting: lysine, methionine, threonine and tryptophan.

**Macronutrients**
Macronutrients are used by the body for energy and provide many of the building blocks for normal bodily functions. They therefore make up the bulk of all the food we eat. There are three kinds of macronutrient: carbohydrates, fats and proteins.

**Methylcellulose**
Methylcellulose is an ingredient made from cellulose. It was invented in the 1950s and became widely used as a thickener and emulsifier in various foods beginning in the 1960s. Like cellulose, it is not digestible, non-toxic, and not an allergen.

**Microbiome**
A microbiome is the community of microorganisms that can usually be found living together in any given habitat. In health terms, this usually refers to the various species of microorganisms that live in our digestive tract.

**Micronutrients**
Micronutrients are vitamins and minerals that are needed by the body for healthy functioning, but only in very small amounts.

**Muscle Protein Synthesis (MPS)**
Muscle Protein Synthesis rate describes the rate at which the body builds muscle tissue. It is generally lower in older people.

**Mycelium**
Mycelium is the root-like structure of a fungus, made up of a network of thin threads, which form the main body of the organism.

**Mycoprotein**
Mycoprotein is a protein ingredient made from fungi. This can either be microscopic fungi or larger fungi like the protein-rich 'roots' of mushrooms known as mycelium.
Quorn is the most widely available example of mycoprotein available today, and has been used as an ingredient since 1985.

**Nordic Keyhole**
The Nordic Keyhole is a front-of-pack nutrition label used in Nordic countries that helps consumers choose healthier food options within product groups, based on the Nordic Nutrition Recommendations.

**NutrInform Battery**
The NutrInform Battery is a front-of-pack label used in Italy (also available in a scanning app for phones), displaying the content of energy, fats, saturated fats, sugars, and salt per serving, along with its contribution to daily dietary requirements, using a "battery" symbol to represent percentages.

**Nutriscore**
Nutri-Score is a colour-coded, front-of-pack nutritional label designed to make a food product's nutritional value easier to understand, using a scale from A (healthiest) to E (least healthy) to help people make informed choices.

**Observational (real-world) studies**
A type of research that uses data from people going about their daily lives, in this context looking for emerging patterns in people grouped by the proportion of their diet coming from UPF. These studies often have the advantage of having a large number of participants, but they are not randomised, meaning it can be hard to know the impact of one single factor relative to other inter-related characteristics linked to poor health such as smoking status. As such, they are mainly used to either identify a theory to be tested in an experimental trial, or to confirm if an outcome seen in an experimental trial still persists in imperfect real-world conditions.

**Precipitated**
A chemistry term describing the process whereby a solid (precipitate) comes out of a liquid solution to form a sediment. It is the opposite process to dissolution, when a solid is dissolved into a liquid to form a solution.

**Precision fermentation**
Precision fermentation is a process that has been used for decades in food production to produce common ingredients such as rennet – used in cheesemaking. It is a process that leverages the natural abilities of certain microorganisms like yeast to over-produce a desired compound, which can then be isolated and used as needed.

**Protein density**
Defined as the amount of protein per 100g.

**Protein quality**
This refers to a combination of both amino acid profile and digestability in proteins. It is typically defined using the PDCAAS, which stands for Protein Digestibility-Corrected Amino Acid Score or the DIAAS which stands for the Digestible Indispensable Amino Acid Score.

**Schijf van Fijv**
The Schijf van Fijv or 'Wheel of five' is the dietary guidance model adopted by the Netherlands. It separates foods into 5 separate groups, each of which has a defined minimum content threshold for desirable nutrients like vitamins and fibre, and maximum thresholds for nutrients of concern liks salt and sugar. Foods meeting these thresholds for its category are included in dietary guidance, which people can check using the 'Kies ik Gezond' mobile phone app.

**Seitan**
Seitan is a food made from gluten, the main protein of wheat, that has been used as a meat alternative for many centuries. It was first developed hundreds of years ago by Buddhist monks in China and Japan.

**Solid-state fermentation**
Solid state fermentation grows a target (such as koji used in Tempeh or mycelium from mushrooms) on a solid feedstock without free flowing water.

**Soluble fibre**
Soluble fiber is a type of dietary fiber that dissolves in water, forming a gel-like substance in the gut which helps to regulate blood sugar and cholesterol levels.

**Textured vegetable protein (TVP)**
Textured vegetable protein (TVP) is a dried protein ingredient that was invented in the 1960's, often coming in the form of small 'mince' pieces or chunks.

**Texturisation**
Processes that are used to create a desired texture in a foodstuff.

**UK Traffic Light system**
The UK traffic light food label system uses red, amber, and green colors to indicate whether a food is high, medium, or low in fat, saturated fat, sugars, and salt, designed to help people understand food labels and make healthier choices.

**Umami**
Umami is the 'savoury' flavour in foods. It is frequently associated with foods like stock, meat and fermented foods.

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