SARAH NÁJERA ESPINOSA, ROSEMARY GREEN AND PAULINE SCHEELBEEK, LONDON SCHOOL OF HYGIENE AND TROPICAL MEDICINE - WRITTEN EVIDENCE (FDO0073)

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List of Acronyms

NPBFs	Novel plant-based foods
LSHTM	London School of Hygiene and Tropical Medicine
NPM	Nutrient Profiling Model
UPFs	Ultra-processed foods
SACN	The Scientific Advisory Committee on Nutrition

Information about the London School of Hygiene and Tropical Medicine

The London School of Hygiene & Tropical Medicine (LSHTM) is one of the world's leading public health universities. Our vision is to help create a more healthy, sustainable and equitable world for everyone, because we believe our shared future depends on our shared health. The Nutrition Group at LSHTM researches the major nutrition and food-related problems that affect human development and well-being, at national and global levels, through conducting high-quality scientific research.

Information about the team

- **Sarah Nájera Espinosa** is PhD candidate at the LSHTM researching the role of novel plant-based foods to transitioning towards more nutritious, affordable, and sustainable diets in the UK. By academic training and educational background, Sarah has a Master's in food security and Bachelor's in environmental studies.

Before coming to LSHTM, Sarah worked at the Food and Agriculture Organization of the United Nations for ~5 years. During this period, she worked across different divisions in various food-related topics such as: food composition; pesticides maximum residue limits; the role of pesticides and microplastics in the human gut microbiome; and the effects of climate change on nutrition and biodiversity.

- **Rosie Green** is a Professor of Environment, Food and Health at LSHTM, and Co-Director of the Centre on Climate Change and Planetary Health as well as leading the Planetary Health research group. She is currently the co-PI of the £6 million Pathfinder Initiative project which identifies health co-benefits of actions to mitigate climate change, as well as the Sustainable and Healthy Food Systems (SHEFS) consortium focusing on food systems in India, South Africa and the UK.

- **Pauline Scheelbeek** is an Associate Professor in Planetary Health & Nutritional Epidemiology at LSHTM, and co-Director of the WHO Collaborating Centre on Climate Change, Health and Sustainable Development. She leads the Accelerating Behaviour Change Towards Sustainable & Healthy Diets in Europe (ABC-SHEADE) project and co-leads the Sustainable and Healthy Food Systems Consortium. She has a wide research portfolio on identifying pathways of dietary change towards healthy and sustainable diets, and solutions that would accelerate such change at population level.

1. Introduction

There is a growing body of literature highlighting the environmental and health challenges caused by animal products, particularly by red and processed meat.[1,2] In the United Kingdom (UK), over the last years there has been an increasing number of people reducing (or attempting to reduce) their animal products intake, particularly meat. In a YouGov survey in 2019, 12% of people reported following a vegan, vegetarian or pescatarian diet.[3] While in 2024 this figure only increased by 4%,[3] in a survey commissioned by RSPCA Assured, almost 40% reported to be flexitarians or actively or subconsciously reducing their intake of animal products.[4] Although the survey related to dietary shifts conducted by YouGov only started in 2019, they estimate that in 2025 half of Generation Z may be following varying degrees of reduced meat diets, due to the higher proportion of younger people following these type of diets in the past years.[3]

Despite growing interest in more sustainable and healthier eating, dietary change has been slow. Adherence to dietary guidelines is minimal throughout the UK, with no major changes over the past decade, whilst greenhouse gas emission footprints of diets remain very high. A 'game changer' (or combination of strategies) is needed to accelerate shifts to healthier and more sustainable diets, and this is extremely urgent given the climate crisis as well as the extremely high burden of disease (and associated costs) linked with sub-optimal diets.

A recent study published by our team found that consumption of novel plant- and fungi-based products have doubled between 2008 and 2019 particularly among women and younger generations.[5] Novel plant-based foods (NPBFs) are plant- and fungi-based products specifically designed to replace and/or mimic animal products. In a large systematic review that we conducted we found that the vast majority of these foods have substantially lower greenhouse gas emissions, land use and blue-water footprints as compared to the animal products they might replace, whilst certain NPBFs could also be a very healthy addition to current diets. For example, some fungi- and legume-based plant-based meats and legume and fruit- and vegetable-based drinks showed to provide up to 66.4% of vegetables and 14.4% vegetables and fruits in a serving size of 80g or 250ml, respectively. Some NPBFs also had typically lower energy density, saturated fat and more fibre than animal products they might replace. Certain NPBFs were also fortified with iron, calcium, iodine and vitamin B12, meeting the recommended daily intakes for these micronutrients.[6] Although these foods have been approved for human consumption by regulatory bodies in the UK, there has also been a lot of confusion among consumers related to their nutritional content and healthiness, because most NPBFs are all classified as 'ultra-processed foods' (UPFs) by the NOVA classification system.

2. *The definition of ultra-processed foods (UPFs) is not a helpful definition*

For decades, advances in food processing technology have allowed the expansion of the food environment with a wide variety of safe foods. These foods were commonly referred to as 'junk foods' and used as an equivalent to 'unhealthy' food, i.e. foods that we should not consume in high quantities. In 2019, the NOVA classification emerged, initially aiming to improve guidance around industrially produced foods available in the Brazilian food environment and therewith improve dietary profiles of the population.[7] NOVA classifies foods into four groups considering the number of ingredients and the level of processing: Group 1- minimally processed; Group 2- processed culinary ingredients; Group 3 – processed foods; and Group 4 – UPFs. When this new classification was published, many, including the Food and Agriculture Organization of the United Nations adopted this categorisation for any diet-related work, and very quickly, the term 'ultra-processed' has become ubiquitous across academia, food industry, retail and other food-related stakeholders. Even the Scientific Advisory Committee on Nutrition (SACN) have identified this classification system as a potentially suitable option for the UK, after reviewing the literature and establishing initial screening criteria on processed foods.[8]

Whilst NOVA is helpful in certain ways, there are also some challenges that reduce the usefulness of the classification system when applied with the aim to improve diets, especially because during its development nutrition was not at the core.[9] Many of these challenges also pertain the UPFs concept:

- First, it remains unknown which components—or combinations of components —of UPFs or highly processed foods are unhealthy. The main health concerns may be related to ingredients such as food additives, changes in the food matrix, the nutritional profile or any by-product formation from packaging or processing which can influence endocrine pathways and the gastrointestinal fate,[10] but no distinction between these components is made in the NOVA classification system or when using the UPFs definition.
- The application of the NOVA classification to individual food products involves a degree of subjectivity on some concepts that are loosely defined but *do* determine whether or not a food should be labelled as UPFs. These concepts include 'wholesome,' 'natural,' 'mass-produced,' and 'raw'.[8] There is certainly some disagreement among technical experts what encompasses each of these terms associated with UPFs. In fact, a survey with nutrition and food experts found low intra-expert consistency using the NOVA classification system, despite each of them being provided with a full list of ingredients in each food.[11]

Furthermore, there are common misconceptions on the consumer end: Ingredients used for processing and intended to extend shelf life must go through a food safety risk assessment and approval in each country or region where they are consumed. While risk assessors do not measure risks of the 'cocktail effect' (i.e., consumption of multiple food additives from various industrially produced foods over a short- or long-term period), all ingredients found in processed or UPFs have been approved for human consumption and are generally deemed safe within recommended average daily intake levels. Despite this formal approval, consumers often associate the term 'ultra-processed' with 'synthetic' and assume that many ingredients, such as additives, are not 'real foods,' and hence harmful for our health.

3. Application of the NOVA system to novel plant-based foods

When applying the NOVA classification system to NPBFs, the vast majority will be labelled as UPFs. UPFs are commonly interpreted as foods with negative health associations, while current available evidence on NPBFs consumption (as substitute for some animal products in a typical diet) shows the opposite. Evidence on plant-based meats suggests positive health outcomes mostly related to better weight management, lower glycaemic markers and lower cardiovascular risk of non-communicable diseases, and positive changes in gut health.[6,12,13] A recent study found that subclassified UPFs revealed that not all UPFs are equal, with a more nuanced subclassification, the authors showed that plant-based meat alternatives were not associated with health risks.[10]

Many UPF foods have been found to be associated with increased risk of diet-related diseases and multimorbidity,[11] due to their energy density, low fibre content and high palatability. By contrast, some NPBFs, that receive the same 'UPF label', exhibit a nutritional profile that aligns with healthy dietary guidelines, such as being high in fibre, contain vegetable, nut and legume content, having low energy density, and low saturated fat (see section 4).

[14-17]The above shows some clear limitations of the NOVA classification system, and the UPFs terminology. NOVA or UPFs would potentially form a major barrier for people to change towards more plant-forward diets, especially if (for reasons of convenience) dietary change would have been aided by the consumption of NPBFs.

4. Health outcomes and nutritional composition of novel plant-based foods (NPBFs)

For the past 5 years our team has been researching the role of NPBFs in sustainable and healthy diets. We recently conducted a systematic literature review to identify the health and environmental outcomes of consuming NPBFs.[6] Although health evidence was limited and relying on

short-term studies of plant-based meat and drinks, the inclusion of NPBFs into diets appears to typically have beneficial health effects, particularly the consumption of plant-based meat alternatives. Evidence on plant-based meats, based on 9 studies, suggests positive health outcomes mostly related to better weight management, lower glycaemic markers and lower cardiovascular risk of non-communicable diseases in high-income (and often obesogenic) countries, good muscle protein synthesis and positive changes in gut health. Our findings are supported by a recently published meta-analysis on blood lipid levels, suggesting positive outcomes in cardiometabolic biomarkers when incorporating plant-based meat alternatives as substitutes for meat in the diet were also identified,[12] and a prospective cohort study that did not find associated dietary-related risks.[10]

Evidence on health effects of plant-based drinks was extremely limited, with only 3 studies reporting health outcomes. They reported some mixed results suggesting similar glycaemic responses in soy-drink consumers as compared to bovine milk consumers, but also some potential concerns about dental health related to soy-based drinks with added sugar, and iodine deficiency among those exclusively consuming soy and almond-based drink alternatives. Evidence on the health impacts of other plant-based drinks and other NPBFs such as plant-based yogurts, cheese and eggs was lacking.

Evidence from our review on NPBFs also suggests that nutritional composition of some individual NPBFs was typically aligned with healthier diets in high-income food secure settings, providing good amounts of fibre, fruit, vegetables, nuts and legumes that are often under-consumed in the UK diet. Most products provided lower energy density, lower total sugar, higher fibre and lower saturated fat content.[6] In our study we identified that certain foods such as mycoprotein and legume-based meats frequently provided good amounts of fibre, vegetables and legumes. This was also true for other products such as legume and fruit and vegetable-based drinks that were found to have lower energy, saturated fat and more fibre.

5. The case for a more nuanced subgroup categorisation

Whilst we believe that some NPBFs could play a crucial role in improving nutritional health and bringing down environmental footprints of the UK food system, we also conclude that there is enormous variability in their nutrient profiles and fruit, vegetable, nut and legume content. Most of them would be classified as UPFs, and hence we argue that a more nuanced subgroup or categorisation would help consumers, procurers, chefs, etc. identify NPBFs that would likely improve the healthiness of their diets and distinguish them from the unhealthier ones.

In Table 1, we given an overview of the nutritional composition of a selection of plant-based meat alternatives, as well as animal products that those NPBFs typically replace. It shows that most plant-based sausages and certain plant-based burgers can form part of a healthy diet with careful consideration of the sodium, total sugar and other micronutrients content.

We suggest that the nutrient profiling model (NPM) could be a good starting point for a further sub-classification. People eat diets rather than individual foods or nutrients, and hence some biological processes may be influenced by combinations of foods that people are eating, many of which are still not fully understood. The NPM is already widely used by the UK government and already scores various nutrients all together. The NPM accounts for energy, saturated fat, total sugar and sodium (Points A) and deducts them with the nut, vegetable and fruit content, fibre and protein content of the food analysed (Points C).[18]

The NPM score could, for example, be an addition to the voluntary traffic light system. This would guide people that consume UPFs, for various reasons including but not limited to necessity, price constrains, convenience, etc., to make more informed decisions on their food choices.

6. Conclusions

We argue that the following steps are crucial to accelerate dietary and food system transformations – both with public health and environmental sustainability objectives in mind:

- There is a clear need for a more nuanced subgroup or categorisation to help various stakeholders identify foods currently labelled as UPFs, particularly NPBFs.
- A potential starting point for this more nuanced classification system could be the NPM that takes into consideration various macronutrients, sodium, and fruit, vegetables and nut content. We suggest this should be clearly labelled.
- We recommend refraining from using classification systems like NOVA, which have not been developed within the UK context and do not offer clear guidance.

This would not only guide consumers, procurers, chefs, etc. but would potentially also allow for a tiered fiscal system where a distinction can be made between unhealthy UPFs and healthy UPFs – including some of the NPBFs as mentioned above.

8 April 2024

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Table 1: Comparison between the median nutritional content of plant-based meats and their animal-based counterparts in 100g of product. Colour code shows how the plant-based product scores against the animal-based comparator. Green is better, while orange is worse than the comparator. The type of colour changes depending on the nutrient, for example if energy is lower in plant-based products it is green, while if iron is lower, it is orange. Data sources: Novel plant-based foods from;[6] animal-based counterparts from UK Food Composition Table ('Food Codes': 19-497, 19-651, 18-503, 19-496, 19-510).

Food Product	Number of products	Energy (kcal)	Protein (g)	Fat (g)	Saturated Fat (g)	Fibre (g)	Total sugars (g)	Sodium (mg)	Iron (mg)	Vit B12 (mcg)
Bacon rashers, back, raw	***10***	***215.00***	***16.50***	***16.50***	***6.20***	***0.00***	***0.00***	***1140.00***	***0.40***	***Tr***
plant-based bacon, total median	4	183.08	19.75	8.45	0.69	4.20	1.30	860.00	0.70	0.13
Legume-based bacon	3	152.00	24.50	1.20	0.30	4.00	1.30	1080.00	0.70	0.13
Mycoprotein-based bacon	1	214.17	10.08	15.71	1.08	5.58	NA	640.00	NA	NA
Burger, beef, 62-85% beef, raw	***10***	***219.00***	***15.90***	***15.20***	***5.72***	***0.70***	***2.70***	***330.00***	***2.10***	***2.00***
PB burgers, total median	95	212.39	15.00	10.00	1.38	4.31	1.75	436.00	0.70	0.13
Legume-based burgers	52	220.62	16.95	11.80	1.35	3.75	0.72	404.00	0.70	0.13
Mycoprotein-based burgers	2	232.25	17.50	11.80	2.55	4.30	2.03	840.00	NA	NA
Fruits & Vegetables-based burgers	23	191.00	4.80	7.90	1.00	4.90	2.70	352.00	0.70	0.13
Cereals & Grains-based burgers	11	246.66	25.00	5.68	0.70	1.50	0.00	251.20	0.00	0.00
Nuts & Seeds-based burgers	7	214.27	13.33	11.10	0.00	4.31	0.00	698.10	2.39	0.00
Chicken/turkey pieces, coated, baked*	**9**	**256.00**	**14.40**	**13.90**	**2.11**	**2.30**	**1.10**	**360.00**	**1.07**	**0.20**
PB nuggets, total median	9	232.00	12.70	11.10	0.90	4.90	1.15	440.00	0.70	0.13
Legume-based nuggets	8	234.50	12.70	11.10	0.90	4.90	1.15	440.00	0.70	0.13
Fruits & Vegetables-based nuggets	1	185.00	3.00	9.40	1.00	3.10	5.10	232.00	0.70	0.13
Ham	**10**	**107.00**	**18.40**	**3.30**	**1.10**	**0.10**	**1.00**	**800.00**	**0.70**	**1.00**
Mycoprotein-based ham	1	122.92	16.58	2.71	1.21	5.42	NA	360.00	NA	NA
Sausages, pork, raw	**NA**	**309.00**	**11.90**	**25.00**	**9.15**	**2.80**	**2.80**	**470.00**	**0.90**	**1.00**

PB sausages, total median	48	159.90	10.65	8.60	1.70	4.99	1.30	520.00	0.70	0.13
Legume-based sausages	26	190.29	13.80	10.02	1.40	4.40	0.70	520.00	0.70	0.13
Mycoprotein-based sausages	3	197.92	13.00	11.08	0.90	5.42	0.00	520.00	NA	NA
Fruits & Vegetables-based sausages	18	145.50	5.66	6.44	1.80	5.81	2.55	454.00	0.70	0.13
Cereals & Grains-based sausages	1	182.00	16.10	9.80	0.80	3.60	1.30	520.00	0.00	NA

*Baked products; Tr: Trace; NA: Not available