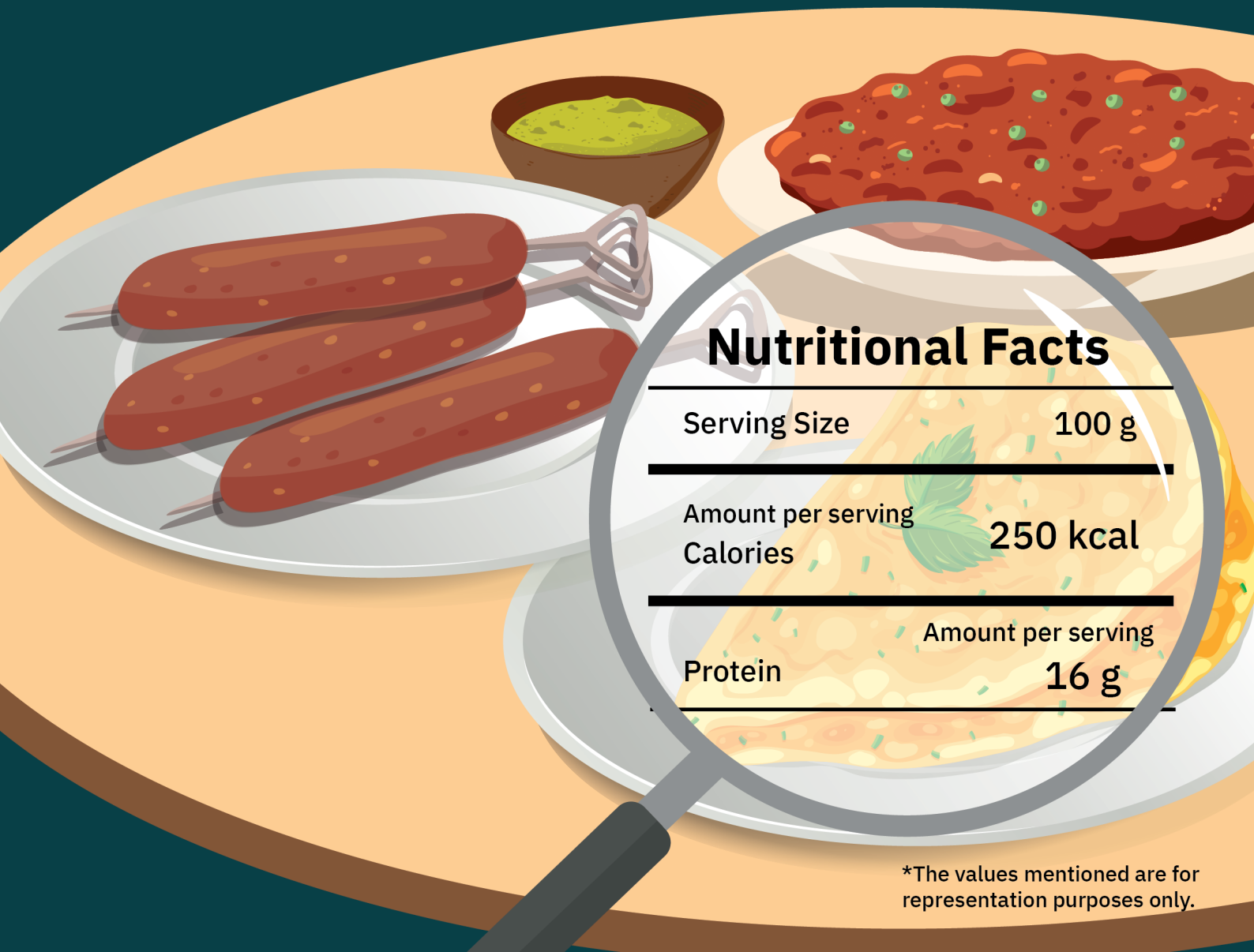
gfi India

Decoding smart protein nutrition

A technical analysis of plant-based meat and egg products in India



*The values mentioned are for representation purposes only.

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Background

India's protein consumption pattern continues to evolve since the country achieved self-sufficiency in food production following the Green Revolution in the 1970s. Over the years, economic development, urbanisation, lifestyle changes, cultural influences, and government policies have continued to determine the main protein sources of the Indian population. Cereals (rice and wheat) and pulses (lentils, chickpeas, beans, and others) are the major plant-based sources of protein in the Indian diet[1]. A combination of cereals and pulses constitutes a complete source of protein in many traditional diets. With dal-chawal*, roti#-dal, khichdi^, or Idli/Dosa/Sambar-Rice$ on the daily meal plate of most Indian households, 'plant protein complementation'@ is an integral part of our diet. In India, consumption of animal-derived proteins gained momentum only during the latter part of the 20th century because of a rapid increase in the production of milk and meat/eggs after 1970 and 1980, respectively[2,3,4]. Higher disposable incomes and a rise in the price of pulses steered the increase in demand for animal-derived proteins in India[1].

According to the United States Department of Agriculture (USDA), Indians have a long history of consuming soybeans, pulses, jackfruit, and dairy for protein[5]. A growing number of Indian consumers are eating more plant-based foods in recent years due to health concerns and awareness of the detrimental effects of industrial animal agriculture on public health, sustainability, and the environment. The expanding ecosystem of plant-based meat, dairy, and egg start-ups and companies is catering to this increasing consumer interest.

Indian consumers are not new to the concept of utilising plant ingredients to mimic meaty textures. '*Soya chaap*' is a famous vegetarian delicacy in the northern part of India, which is often touted as a meat substitute owing to its taste and texture. Similarly, raw jackfruit is a preferred ingredient in savoury dishes due to its fibrous texture that mimics meat. A tomato omelette is a popular breakfast dish or street food prepared in Maharashtra in which chickpea flour (besan) is used to bind and thicken the dish, similar to eggs. Many of the early plant-based meat products were designed with vegetarian consumers in mind and did not try to precisely replicate conventional meat.

*stew made of lentils/pulses & rice; #flat bread; ^a traditional Indian dish made from rice and lentils, often cooked with various spices and sometimes vegetables; $Steamed rice cakes, crispy rice and lentil crepes and a spicy lentil soup, often made with vegetables; @A scientific approach to obtain complete amino acid profile.

The endeavour to develop plant-based meat products with taste, texture, and nutritional parity with animal-derived products is more recent and caters to meat eaters, particularly flexitarians who look for healthy and sustainable alternatives to conventional meat products.

What motivates the Indian consumers to buy plant-based meat products? GFI India's survey[6] reveals that 47% of Indians are driven to eat plant-based meat because of its protein content, while 33% and 30% are drawn to its convenience and ease of cooking and cleaning, respectively. Another recent study on the comparative experience of plant-based and animal-derived meat products among Indian consumers shows that they read the list of ingredients and nutritional labels (protein content and cholesterol) of plant-based meat products[7]. Over 72% of the households that purchased plant-based meat in the last six months were interested in repeat purchases. Nutrition, health, and protein content are the key reasons mentioned by consumers for the repeat purchase of plant-based meat products[6]. **All of these studies indicate that while meat consumption is mainly driven by taste, nutrition and health are significant catalysts for the purchase of plant-based meat products.**

The Indian plant-based egg sector is still in its nascent stages. However, its application range and market opportunities are promising. Depending on ingredients, the plant-based egg products can provide comparable or more protein and calcium and less or zero saturated fat than conventional egg products. Moreover, the plant-based egg products are typically 'cholesterol-free', which is an added nutritional advantage over conventional egg-based products.

Motivation for the nutritional assessment of plant-based meat and egg products in the Indian market

Nutrition is not limited to protein and calories. A nutritious food is *"one that provides beneficial nutrients (e.g., protein, vitamins, minerals, essential amino acids, essential fatty acids, dietary fibre) and minimises potentially harmful elements*[8,9,10] *(e.g., anti-nutrients, quantities of sodium, saturated fats, sugars)".* The amount of macronutrients and micronutrients in a food and their ability to meet the dietary requirements of consumers govern its nutritional quality. The growing consumer interest in plant-based alternatives to animal-derived products necessitates the understanding of their nutritional content and health benefits in comparison with their conventional counterparts. Several early adopters of plant-based meat rate these products higher on health and nutrition compared to animal-derived products. However, scientific data is essential to instil confidence among consumers around the nutritional and health aspects of plant-based meat and egg products. Besides, a comparative dataset would aid in identifying the areas of improvement related to the nutritional parity between plant-based and conventional meat and egg products.

This technical brief is based on a study conducted in two phases:

Phase-1: Compilation and comparison of the nutrition labels and ingredient lists of plant-based meat and egg products available in the Indian market vis-à-vis the corresponding animal-derived products.

Phase-2: Quantification of the amino acid and fatty acid composition of selected plant-based meat and egg products to determine their nutritional quality and establish correlations with their protein and fat sources, respectively.

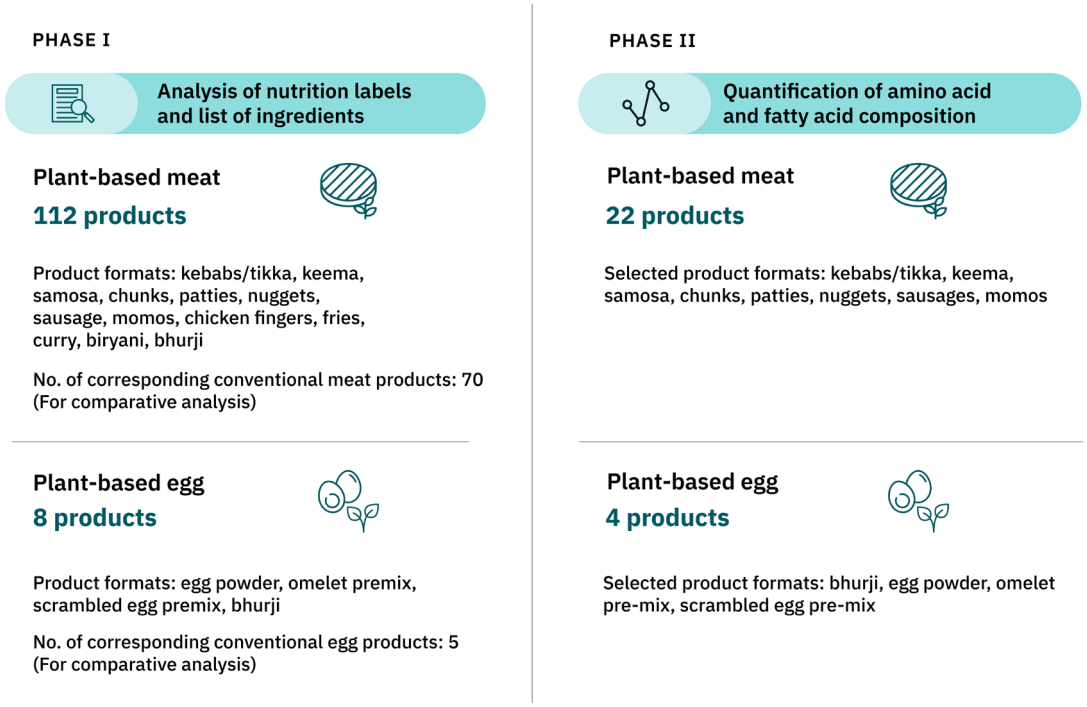


Image-1: Phases of the study and research plan

Understanding the nutrition labels of plant-based meat and egg products

According to the Food Safety and Standards Authority of India (FSSAI)[11], nutritional information is a description intended to inform consumers about the nutritional properties of foods. 'Nutrient' refers to a *"constituent of food, which provides energy (or) has specific metabolic or physiological functions (or) is needed for growth and development and maintenance of healthy life".* All packaged foods are mandated to include numerical information about the nutritional composition, including, energy, protein, carbohydrates, total sugar, added sugar, total fat, saturated fat, trans-fat, cholesterol, and sodium, in their back-of-pack labelling. Besides, a food product that is claimed to be enriched with nutrients such as minerals, proteins, vitamins, amino acids, or enzymes must declare the quantities of the added nutrients on the label. Parameters to judge the nutritional quality of food products, such as amino acid composition or score, digestibility of proteins, fatty acid profile, bioavailability of nutrients, concentrations of bioactive compounds, and anti-nutrients, are not normally part of nutrition labels[11]. While energy is represented in calories, the amount of macronutrients is expressed per 100 g (or 100 mL for liquid products) and/or per serving of the product. Cholesterol, sodium, calcium, and potassium contents are stated in mg per 100 g or serving of the product and micronutrients are expressed in µg per 100 g or serving of the product.

Plant-based meat and egg products in the Indian market are available in a wide range of formats, including western products like patties, sausages, nuggets, and scrambled eggs, as well as Indian formats like kebabs, tikka, keema, biryani, samosa, bhurji, and so on[7]. The nutrition labels of many plant-based meat and egg products provide information on how a single serving of the product contributes (in percentage) to the Recommended Dietary Allowance (RDA[#]) for Indians as specified by the Indian Council of Medical Research (ICMR) and the National Institute of Nutrition (NIN)[12].

- Nutrition labels of 11% of the plant-based meat products available in the Indian market include quantitative information on the 'calories from fat' (in kcal). According to the ICMR-NIN's 'Dietary Guidelines for Indians'[12], a balanced diet should ensure 50–55% of the total calories come from carbohydrates, 10-15% from proteins, and 20–30% from dietary fats. The EAT-Lancet's reference diet recommends 29% of the calories to be derived from protein sources[13].

[#]RDA is calculated on the basis of 2000 kcal energy, 67 g total fat, 22 g saturated fat, 2 g trans-fat, 50 g added sugar and 2000 mg of sodium (5 g salt) requirement for an average adult per day.

- The back-of-pack labels of certain plant-based meat and egg products present comparative information on their nutritional parameters versus chicken's egg, goat meat, buffalo's milk, and raw chicken (whole). This is a useful piece of information for consumers who wish to make an informed choice when they prefer to switch from a non-vegetarian to plant-based diet.

	Nutritional Information (Per 100 g)		
		Per 100 g	% RDA* Per Serve
MACRONUTRIENTS	Energy	....kcal	....%
	Total Carbohydrates	....g	....%
	Total Sugar	....g	....%
	Added Sugar	....g	....%
	Dietary Fibre	....g	....%
	Protein	....g	....%
	Total Fat	....g	....%
	Saturated Fat	....g	....%
	Trans Fat	....g	....%
	Cholestrol	....g	....%
MICRONUTRIENTS	Sodium	....mg	....%
	Vitamin B12	....mcg	....%
*Recommended Dietary Allowance calculated on the basis of 2000 kcal energy requirements for an average adult per day.			
Serve Size: g		No of Serving:	

Image-2: A model nutritional label of a plant-based meat product

Decoding the ingredient lists of plant-based meat and egg products

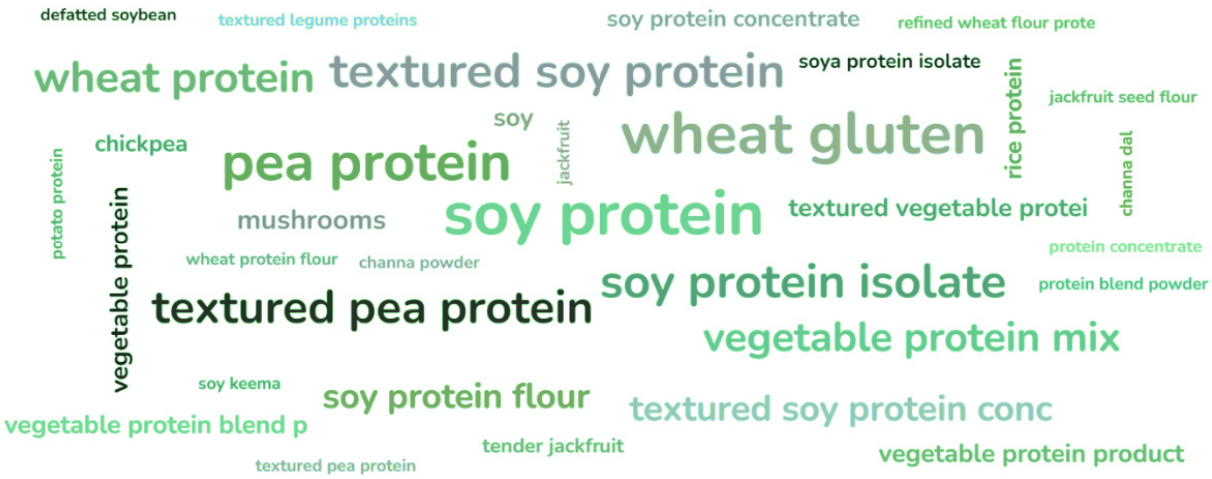
The ingredients section on the back-of-the-pack labels of plant-based meat and egg products includes a wealth of information. Food ingredients are listed in descending order of their composition (by weight or volume) in the product, as the case may be at the time of its manufacture[14]. This technical brief focuses on the sources of protein, fat, and dietary fibre in the plant-based meat and egg products in order to establish correlations with their quantities declared in the nutrition labels and the amino acid and fatty acid composition determined in Phase-2 of this study.

- Of the plant-based meat products, 30% employ soy as their sole source of protein, 20% use a composite blend of soy protein and wheat gluten, and 16% contain pea protein. The remaining products use different combinations of plant-based proteins: (soy+legumes/pulses/lentils), (soy+wheat+legumes/pulses/lentils). Among the plant-based egg products, 25% use a combination of soy and pea as the protein source. The remaining share of 75% is equally shared by the following protein sources or composite protein blends from chickpea, soy, cowpea, black-eyed pea, {pea, soy, mung bean & chickpea}, and {soy & wheat}.

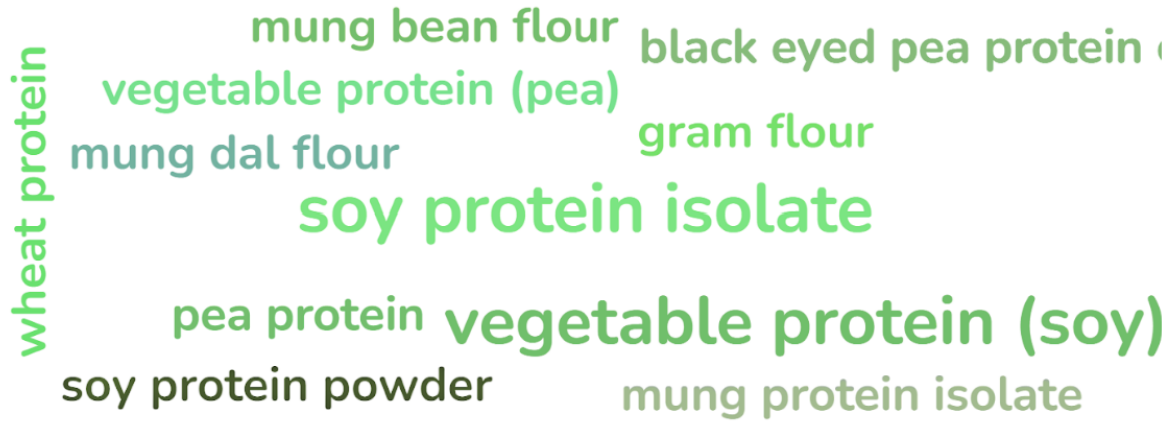
- With respect to fat, while some plant-based meat products use a single source, other products use a combination of sources. 20% of the plant-based meat products use sunflower oil as their fat source. Canola oil and rice bran oil are the sources of fat in 4.3% and 3.5% of the products, respectively. Out of the eight plant-based egg products considered in this study, only three products declare the presence of edible oil in their list of ingredients, of which two products specify soybean oil as the fat source.

- The fibre content of plant-based meat and egg products can be attributed to flour-based ingredients derived from wheat, oats, rice, soy, quinoa, barley, konjac, and corn. Other ingredients contributing to the dietary fibre content of plant-based meat are pea fibre, inulin, and psyllium husk.

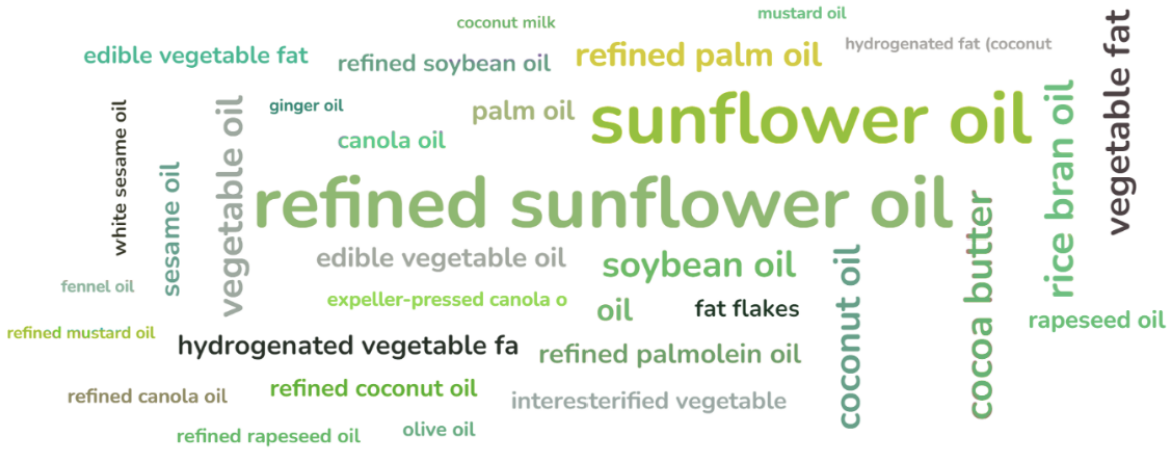
Protein sources of plant-based meat products



Protein sources of plant-based egg products

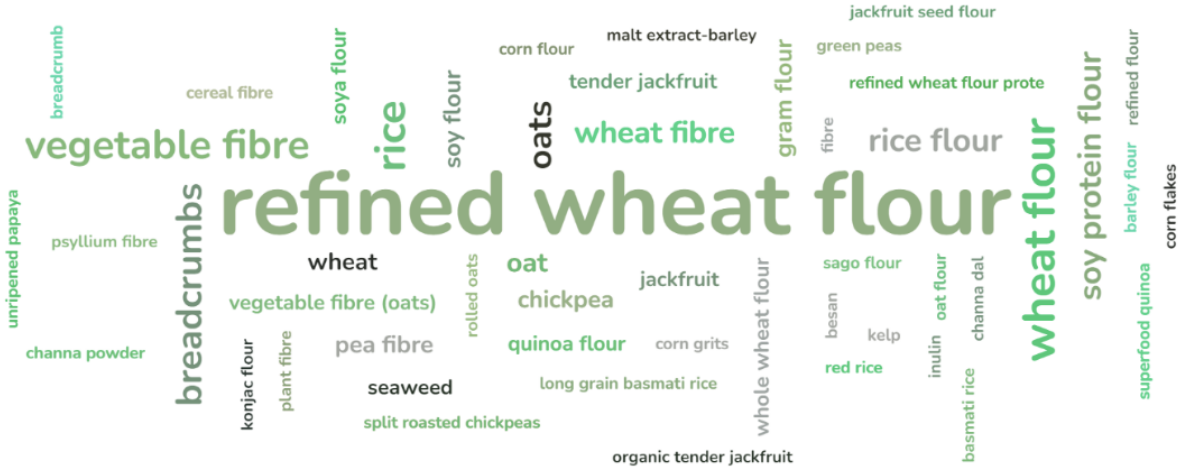


Fat sources of plant-based meat products



Fat sources of plant-based egg products

Sources of dietary fibre in plant-based meat products



Sources of dietary fibre in plant-based egg products

Image-3: Sources of protein, fat and dietary fibre in plant-based meat and egg products

Protein and amino acid composition

Proteins are polymers of amino acids linked together by peptide bonds. Amino acids are small organic molecules that function as the building blocks of proteins. There are 20 different amino acids, of which nine are designated as 'essential amino acids' because the human body cannot produce them. Hence, the essential amino acids must be obtained from food. Protein content (measured in % or g per 100 g) is the key macronutrient in plant-based meat products, as global alternative protein researchers are focused on devising approaches to match FAO's requirements for meat[15].

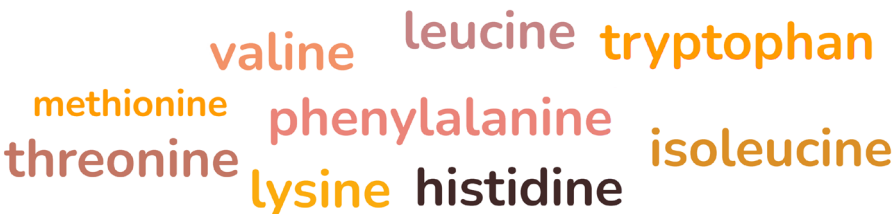


Image-4: List of essential amino acids

Most of the plant-based meat and egg products in the Indian market contain a comparable or higher protein content relative to their corresponding conventional meat and egg products.

- The average protein content of different plant-based meat formats ranges between 9.1% and 20.8%. Notably, plant-based meat products using a combination of soy+wheat and soy+wheat+pea offer a significantly higher protein content (more than 20 g/100 g of the product). According to the nutrient claim conditions specified by FSSAI[11], all the plant-based meat products can be considered as a 'source of protein' (> 5.4 g per 100 g of product). Except for nuggets, sausage, momos, and biryani, the average protein content of other plant-based meat formats complies with the requirements for the 'high-protein' claim (> 10.8 g per 100 g of product).

- Plant-based egg products have a wider range of protein content (8-50%) than plant-based meat products. The average protein content of all the plant-based egg formats is higher than the condition specified by FSSAI for the 'high protein' claim.

[11]FSSAI's protein content claims and requirements: Source: 10% of Recommended Dietary Allowance per 100 g for solids; Rich / High: 20% of Recommended Dietary Allowance per 100 g for solids

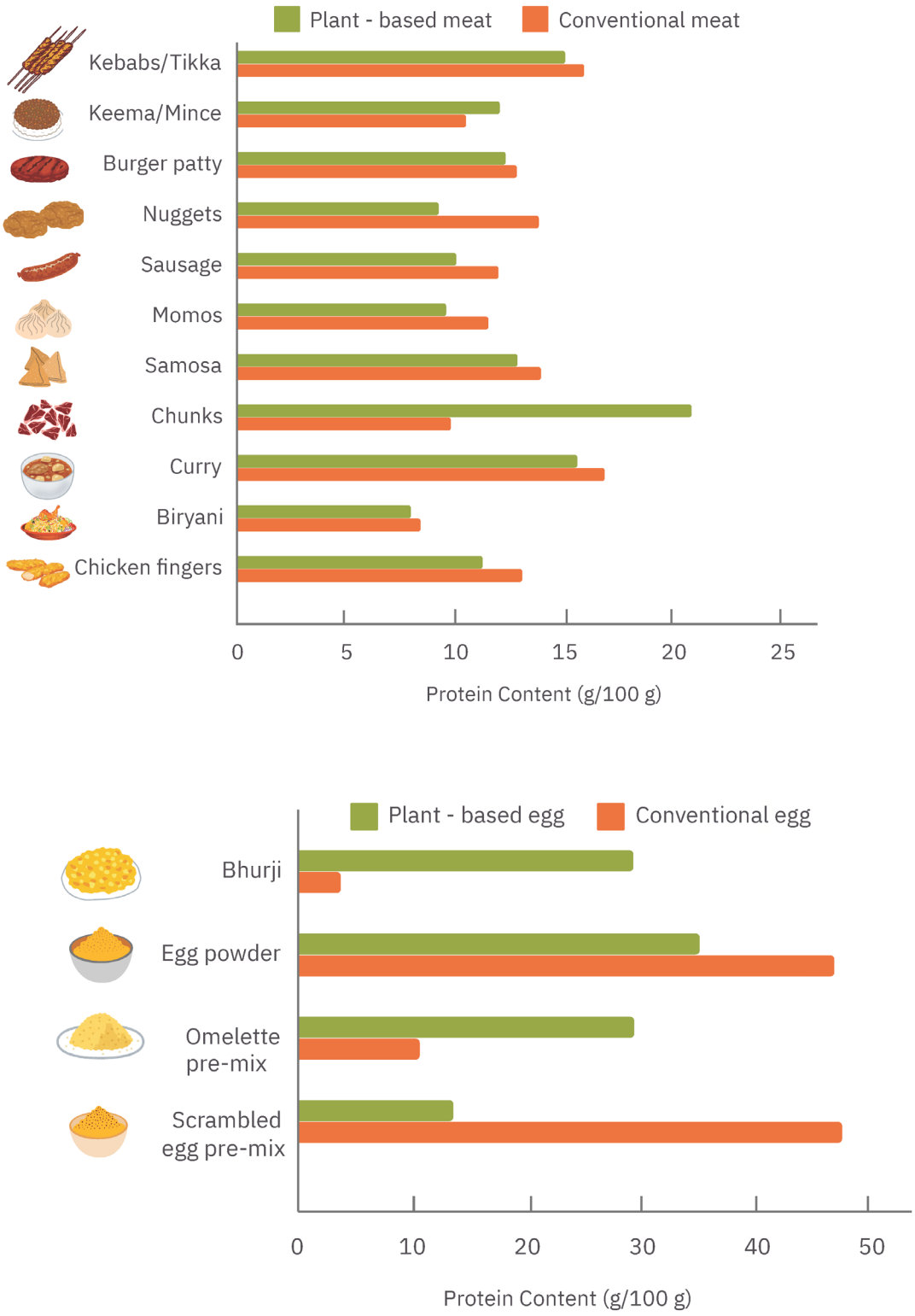


Image-5: Comparison of protein content: Plant-based meat and egg products Vs. conventional products

The total content of different amino acids in different plant-based meat products considered in this study ranges between 0.37 and 19.91 g/100 g. Glutamic acid is the amino acid present at the highest concentration in all the plant-based meat and plant-based egg products tested, irrespective of their format.

- Both the sulphur-containing amino acids (SAAs), i.e., methionine and cystine, are present below 0.1 g/100 g in plant-based keema, nuggets, sausage, momos, and samosa. Cystine is the only amino acid to be present below the detection limit (0.1 g/100 g) in patties and chunks. This is reasonable since SAAs and tryptophan are the limiting amino acids[¤] of soy and pea (legume) proteins[16,17], which are the predominantly used protein sources in these products. Tryptophan is the amino acid at lowest concentration in pea and jackfruit-based keema, pea-based patties, nuggets, sausages, momos, and soy-based samosa. In the jackfruit-based keema product, except for aspartic acid and alanine, the concentration of other 16 amino acids is found to be less than 0.1 g per 100 g.

- Contrastingly, methionine is present at a concentration equal to or above the detection limit in plant-based chunks, kebabs, and patties containing a combination of soy protein and wheat gluten and soy, wheat, and pea proteins. This is justified as methionine is not the limiting amino acid in wheat gluten. Similarly, tryptophan is detected (0.17 g/100 g) in one of the two plant-based patty products containing a blend of soy protein and wheat gluten. This validates the effectiveness of the 'protein complementation' approach, which enhances the utilisation efficiency of a poor-quality protein by combining with another protein. Two protein sources with a more balanced mixture of amino acids provide an essential amino acid pattern approximating or equal to those found in animal proteins[18].

- The total concentration of 18 different amino acids in the four plant-based egg products tested in this study ranges between 15.56 g/100 g and 57.45 g/100 g. The plant-based egg powder product with mung bean as the protein source has the highest total amino acid content (57.45 g/100 g). As observed in the case of plant-based meat products, glutamic acid is present at the highest concentration in plant-based egg products regardless of the format. Cystine is the amino acid that is present at the lowest concentration in all the product formats, irrespective of the protein source (soy, pea, mung bean, and chickpea).

[¤]A limiting amino acid is an essential amino acid that is present in the smallest amount relative to the body's needs for protein synthesis.

Image-6: Amino acid composition of plant-based meat and egg products

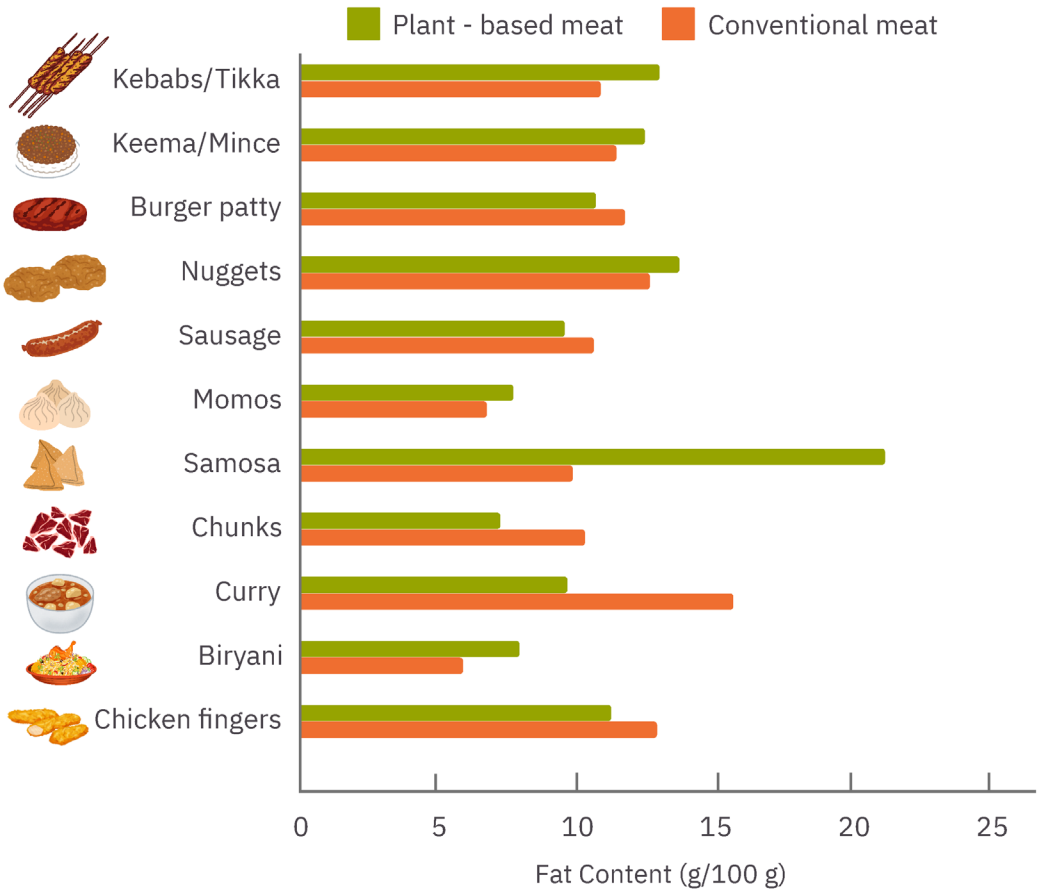
Fat, saturated fat, and fatty acid composition

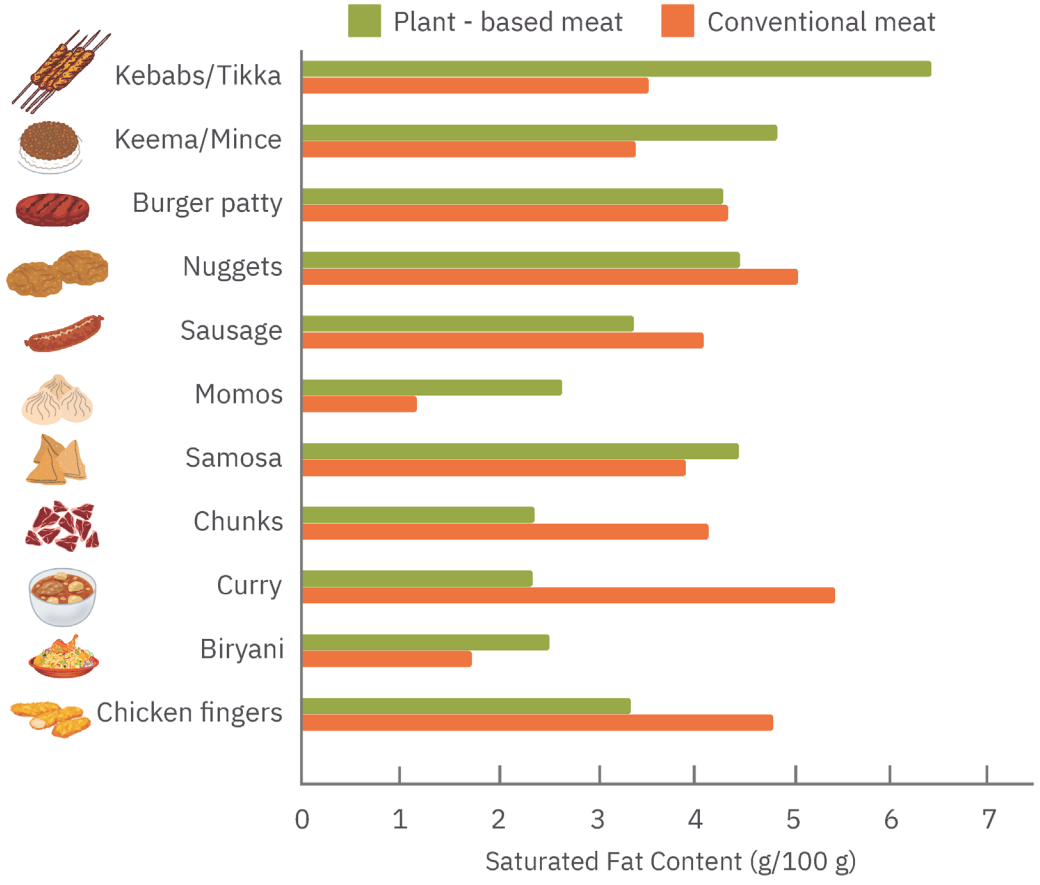
Dietary fats and fatty acids play a major role in immunity building, vitamin absorption, and providing flavour to food[19]. High amounts of saturated fatty acids (SFA) and trans fats have been predicted to cause various health implications, such as increased risk of cardiovascular disease, allergies, diabetes, obesity, and nervous system disorders[20].

- Except samosa, all the other formats of plant-based meat products have a lower or comparable average fat content relative to their animal-derived counterparts. The plant-based chunks, curry, and strip formats show a lower mean saturated fat content than the corresponding conventional products. The total fat content and saturated fat content of both plant-based and conventional meat products do not meet the requirements for the 'free' or 'low' claims specified by the FSSAI[11].

- All the formats of plant-based egg products have a lower total fat content than the conventional egg equivalents. Notably, the plant-based egg powder and scrambled egg premix formats have 78% and 91.2% lower fat content than their corresponding conventional egg products. A similar trend is observed with saturated fat content. However, the total fat content and saturated fat content of the plant-based and conventional egg products do not meet the conditions for the 'fat-free' or 'low-fat' claims put forth by the FSSAI[11].

FSSAI's fat & saturated fat content claims and requirements: Low fat: Not more than 3 g of fat per 100 g for solids; Free from fat: Not more than 0.5 g of fat per 100 g for solids; Saturated fat: Low: Not more than 1.5 g per 100 g for solids and must provide not more than 10% of energy from saturated fat; Free: Do not exceed 0.1 g per 100 g for solids.[11]


Plant - based meat
Conventional meat
Kebabs/Tikka
Keema/Mince
Burger patty
Nuggets
Sausage
Momos
Samosa
Chunks
Curry
Biryani
Chicken fingers
0
5
10
15
20
25
Fat Content (g/100 g)


Plant - based meat
Conventional meat
Kebabs/Tikka
Keema/Mince
Burger patty
Nuggets
Sausage
Momos
Samosa
Chunks
Curry
Biryani
Chicken fingers
0
1
2
3
4
5
6
7
Saturated Fat Content (g/100 g)

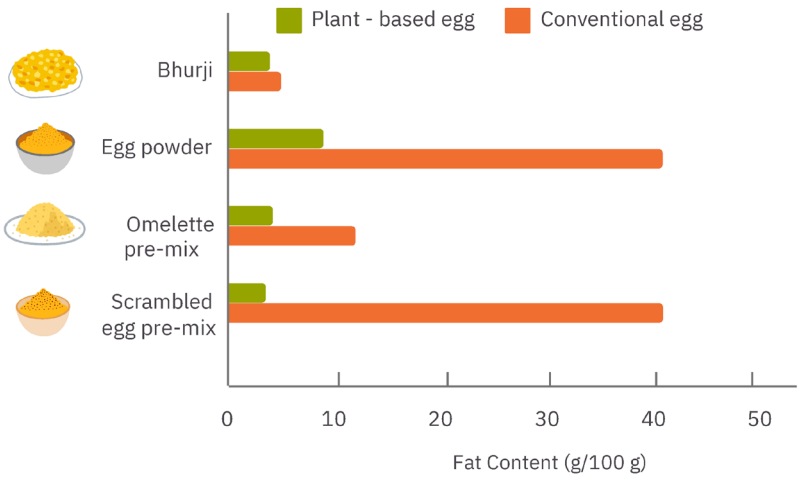


Image-7: Comparison of fat and saturated fat content: Plant-based meat and egg products Vs. conventional products

- Of the three plant-based keema products examined, monounsaturated fat (51.7%) accounts for more than 45% of the total fatty acids. More than 45% of the total fatty acids in the tested products, including two out of the three plant-based kebabs, are derived from polyunsaturated fat (55.18% and 54.71%; fat sources: refined sunflower oil and refined canola oil, respectively), one out of the four patties (54.8%; fat source: refined sunflower oil), one out of the three sausages (48.79%; fat source: refined sunflower oil), and the plant-based scrambled egg premix (46.2%). This corroborates with the fatty acid composition of their respective fat source in the list of ingredients. However, the energy provided by the monounsaturated fatty acids (MUFA) and polyunsaturated fatty acids (PUFA) contents of these products does not exceed 20% of the energy derived from the product.

- The tested plant-based egg powder and scrambled egg products fulfil the requirement to claim being a 'source' of omega-3 fatty acids. But, the plant-based meat products need improvement to fulfil the nutrient content claims on MUFA, PUFA (specifically, the energy derived from MUFA and PUFA) and omega-3 fatty acids.

- Unlike the plant-based meat products, the tested plant-based egg powder and scrambled egg products fulfil the requirement to be claimed as sources of omega-3 fatty acids. The plant-based egg products across various formats, such as bhurji, powder, omelette, and scrambled egg, show relatively similar fatty acid profiles, with the exception of high amounts of linoleic acid in the scrambled egg sample. It is possible that the chickpea powder used as the protein source contributes to the linoleic acid, which is the predominant PUFA in chickpea powder[21].

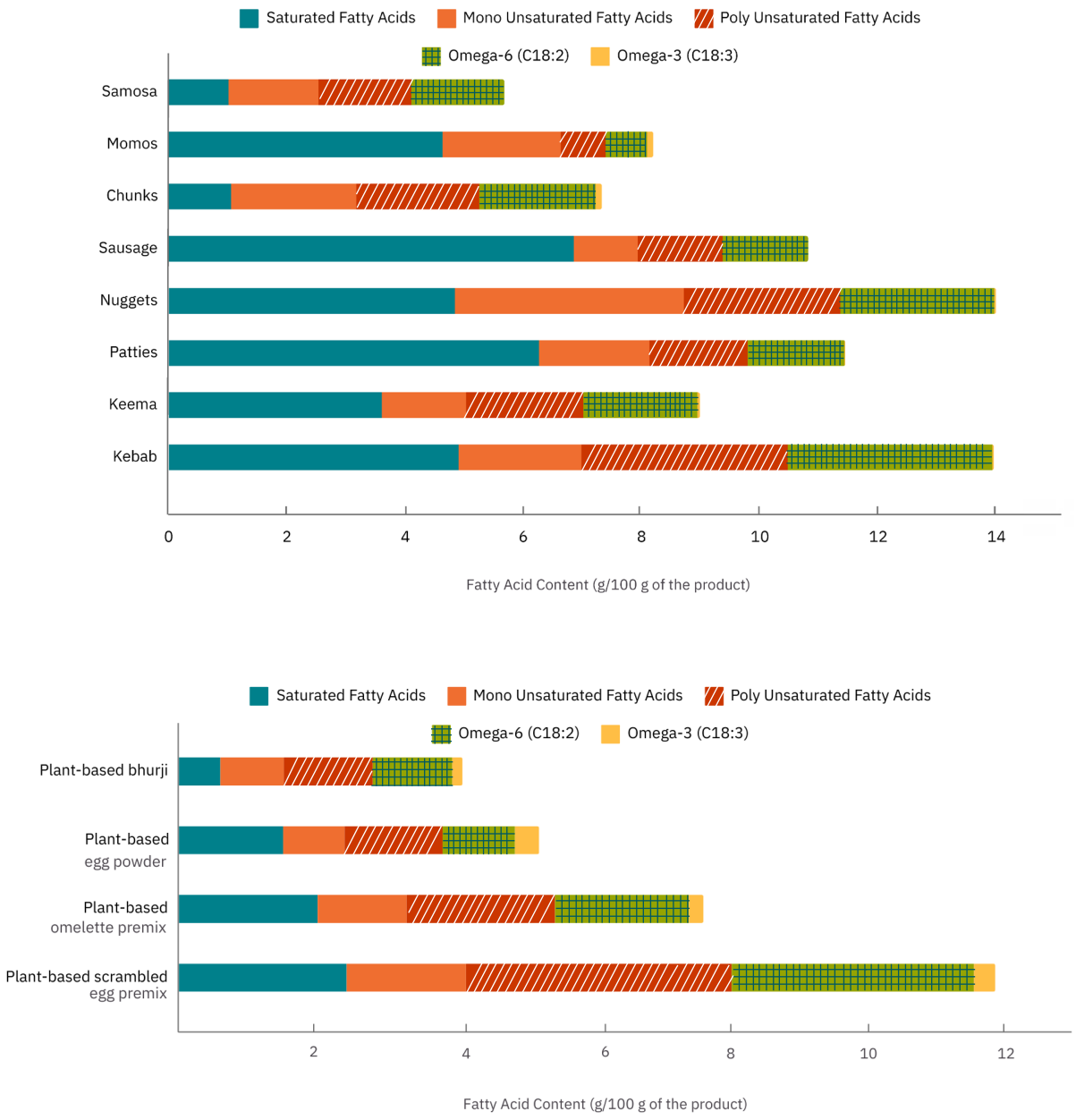


Image-8: Fatty acid composition of plant-based meat and egg products

[11]FSSAI's fatty acid content claims and requirements: High in MUFA: Shall only be made where at least 45% of the total fatty acids present in the product are derived from monounsaturated fat and under the condition that monounsaturated fat provides more than 20% of energy of the product; High in PUFA: Shall only be made where at least 45% of the total fatty acids present in the product are derived from polyunsaturated fat and under the condition that polyunsaturated fat provides more than 20% of energy of the product; Source of Omega 3 fatty acids: The product contains - at least 0.3 g alpha-linolenic acid per 100 g or per 100 kcal; High in Omega 3 fatty acids: The product contains: at least 0.6 g alpha-linolenic acid per 100 g.

Dietary fibre

Fibre is an essential component of a balanced diet. According to the FSSAI[11], foods having at least 3 g of fibre per 100 g (or 1.5 g per 100 calories) are considered a source of dietary fibre. Further, high-fibre foods are those that contain at least 6 g per 100 g (or 3 g per 100 calories).

- While none of the animal-derived products meet these criteria, all the plant-based meat products in the Indian market can be considered a 'source of fibre'. Indeed, except the biryani format, all the other plant-based meat product formats fall within the '*high fibre*' category.

- The plant-based egg products have an average dietary fibre content in the range of 6.43-13.95 g, with the omelette pre-mix category having the maximum value. Therefore, these products can also be considered 'high in fibre'.

Thus, the plant-based meat and egg products in the Indian market are 'high/ rich in dietary fibre', which is a noteworthy advantage over the animal-derived products.

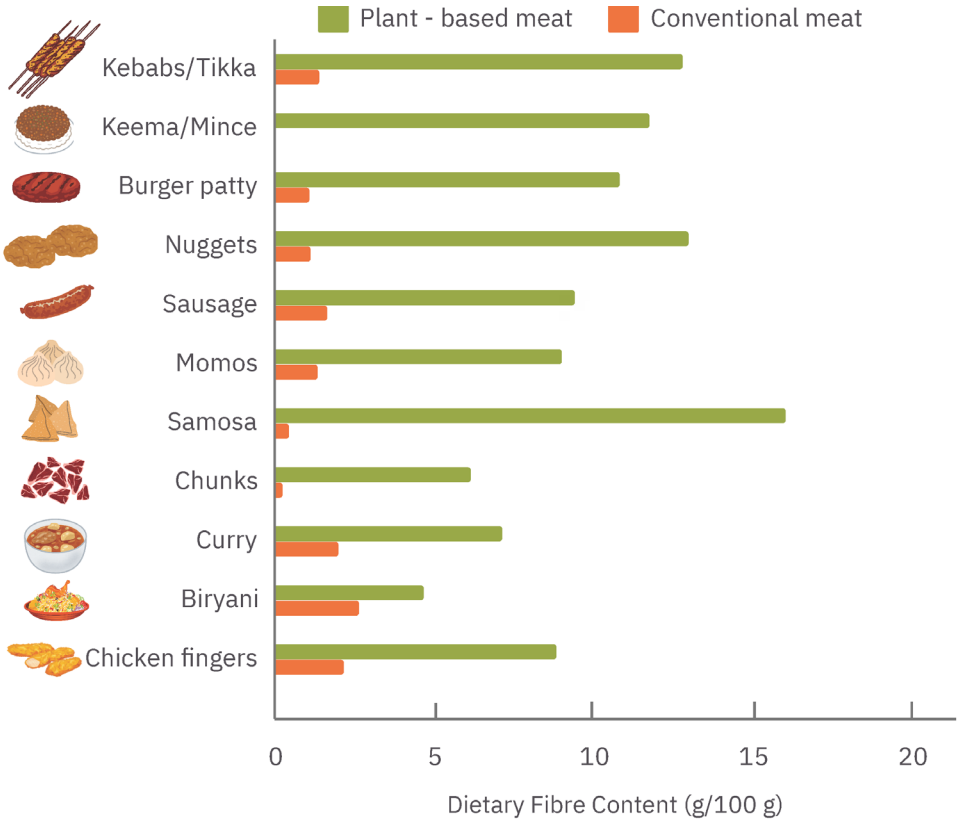


Image-9: Comparison of dietary fibre content: Plant-based meat Vs. conventional meat

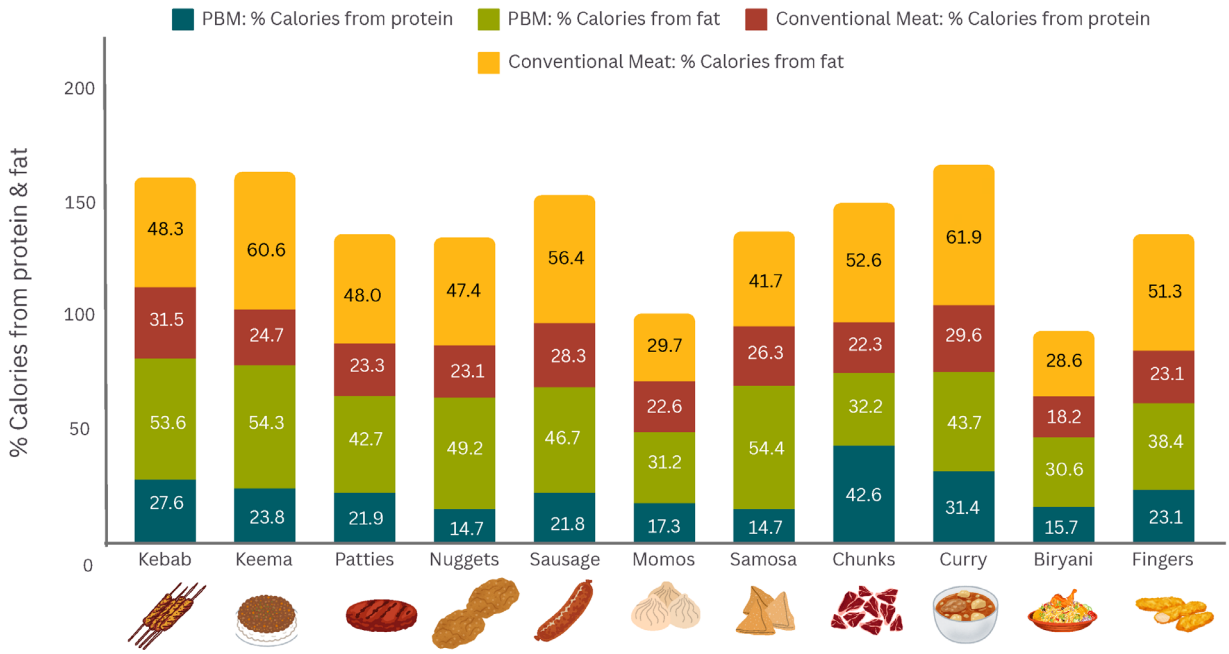
[11]FSSAI's dietary fibre content claims and requirements: Source: Product contains at least - 3 g of fibre per 100 g for solids; Rich / High: The product contains at least - 6 g of fibre per 100 g for solids

Energy

The calories provided by different formats of plant-based meat and egg products (per 100 g) range between 169-349 kcal and 249-378 kcal, respectively. Dietary guidelines typically characterise nutritional protein sources not just in terms of weight-based protein content but also in terms of the proportion of protein-containing calories in a product (as opposed to other macronutrients like fat or carbohydrates).

- With respect to energy derived from protein sources, most of the plant-based meat product formats are comparable to conventional meat. The chunk and curry formats derive 42.6% and 31.4% of calories from protein, compared to 22.3% and 29.6% for their respective conventional products. These values are comparable with the recommended share of calories from protein sources (29%) specified in the reference diet of EAT-Lancet[13].

- Similarly, the plant-based egg formats except the scrambled egg premix derive more than 29% of calories from protein. Six out of the eleven plant-based meat formats and all the plant-based egg formats derive lesser calories from fat than the corresponding conventional meat product formats.



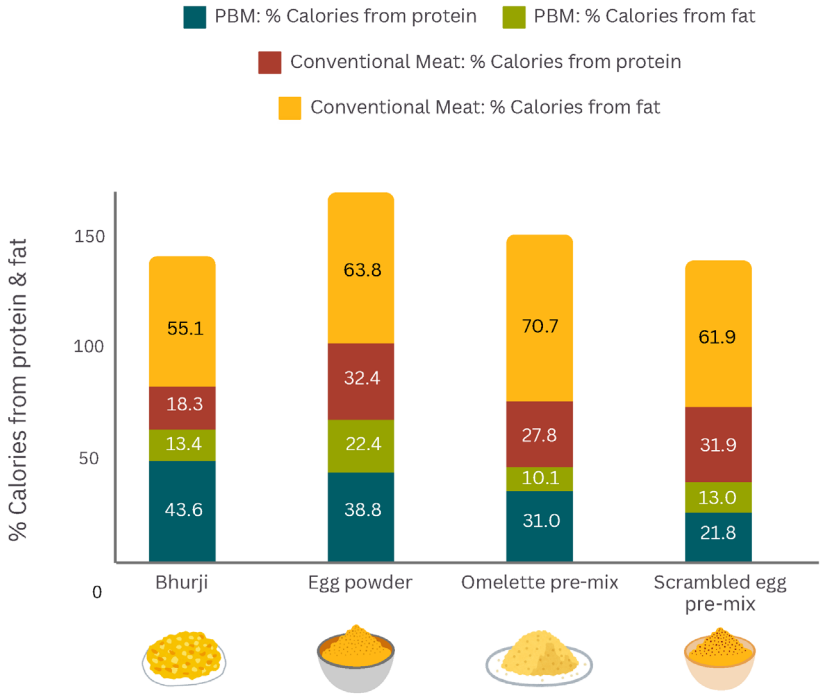


Image-10: Comparison of the share of calories from protein and fat sources: plant-based meat & plant-based egg products Vs. conventional products

Sodium

High salt content is a common dietary concern associated with any processed food product. Generally, high salt intake is linked to high blood pressure, hypertension, and related heart ailments and stroke. Despite its disadvantages, consumption of sodium at an optimal level is essential for water and fluid balance and electrolyte equilibrium. Further, sodium plays a vital role in nerve conduction.

- The average sodium content is either similar or higher in most plant-based meat products compared to conventional meat. Plant-based sausages have a lower sodium content than meat sausages.

- Three out of the four plant-based egg product formats contain higher sodium content than their conventional counterparts. The plant-based scrambled egg pre-mix contains lower sodium content than the chicken egg-based counterparts.

It is important to note that the plant-based meat and egg products in the market often aim to replace similar processed conventional meat and egg products, which are also high in sodium. Plant-based products have already been seasoned at the point of sale and are typically ready to eat, which is not the case with conventional, unprepared, or unprocessed meat. It is observed that the difference substantively reduces after meal preparation[22].

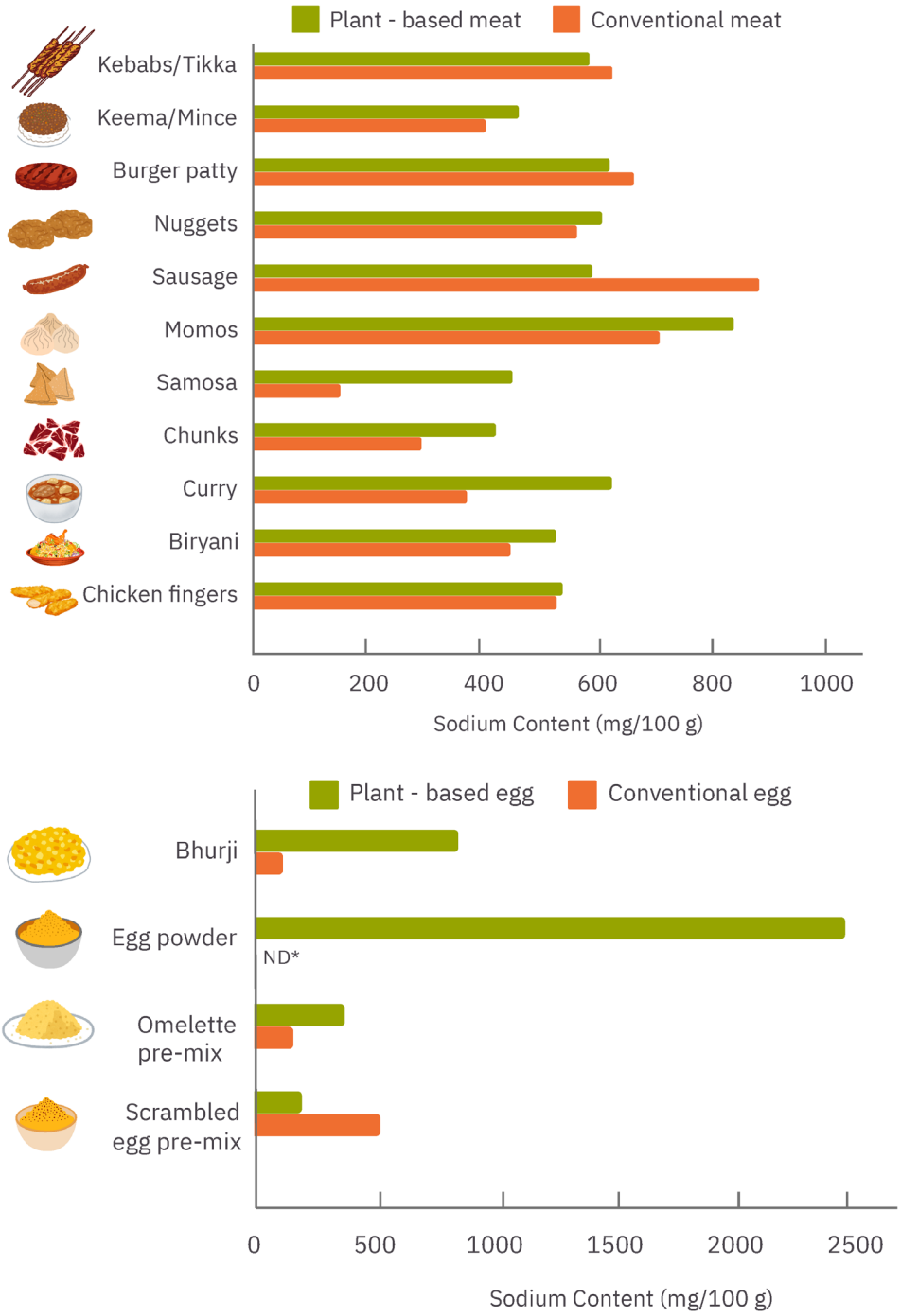


Image-11: Comparison of sodium content: plant-based meat & plant-based egg products Vs. conventional products

*(*Data not available)*

Micronutrients

The micronutrient content of plant-based meat and egg products compared to conventional animal meat depends on their ingredients[23]. Legumes, grains, vegetables, and seeds used in plant-based foods can provide vitamin C, vitamin A, folate, and minerals like magnesium and potassium.

- One product each from the plant-based meat chunks and curry categories shows considerable levels of iron, with one serving accounting for 60.9% and 51.6% of the RDA for iron[24] in the case of adult males and 39.9% and 33.8% in the case of adult females, respectively. The vitamin A content of plant-based kebab products in the Indian market is higher than the conventional products (34.08-289.73 µg/100 g vs. zero or below detectable limits in the conventional products). The RDA of vitamin A for adult Indian men and women is 1000 µg/day and 840 µg/day, respectively[24]. Every serving of the plant-based egg bhurji products contributes 17.6-27%, 5.7%, and 5.9% of the RDA for iron, vitamin C, and calcium, respectively. The plant-based omelette product provides 6.5%, 6.6%, and 39.9% of the RDA for vitamin A, vitamin C, and calcium, respectively.

- Plant-based sausages contribute 4.4% of the RDA for vitamin C per serving. Similarly, plant-based patties and kebabs contribute 2.4% and 4.5% of the RDA for vitamin C per serving, respectively.

- Two plant-based sausage products contain vitamin B12 at a level that contributes to 34.1% of the RDA per serving. Plant-based meat and egg products provide an opportunity for consumers, particularly vegans and vegetarians, to receive recommended amounts of vitamin B12.

- A single serving of plant-based patties, chunks, curry, and sausages provides 8.6%, 8.75%, 12%, and 30.3% of the RDA for calcium, respectively. The calcium content of plant-based kebabs is observed to vary between the products, and their contribution to the RDA for calcium per serving ranges between 13.9 and 83.7%.

The data shows that many of the plant-based meat and egg products do not provide all the micronutrients. Adopting strategies such as biofortification in the upstream stages of the plant-based value chain (say, crop development and cultivation) can improve the content and bioavailability of nutrients in food crops[25]. Further, processing-based ingredient optimisation approaches such as sprouting, enzymatic treatment and controlled fermentation under standardised conditions can enhance micronutrient levels in the different plant-based ingredients used in these products. Adding nutrients (vitamins or minerals) in quantities not exceeding one Recommended Dietary Allowance of the respective micronutrients as per the regulatory guidelines[26] could also be a plausible approach to improving micronutrient content in these products.

Conclusions

The findings of this study show that the plant-based meat and egg products available in the Indian market offer consumers an option to switch their dietary choices by providing a comparable or higher protein and dietary fibre content than their animal-derived counterparts. The results also show the heterogeneity in nutritional aspects across and within the different formats of plant-based meat and egg products. This data is useful in establishing the nutritional stance of plant-based meat and egg products in the Indian market, with reference to the Indian regulations related to nutrient content claims. Ingredients of these plant-based foods have a significant correlation with their nutritional quality. Complementation between certain sources of plant protein, such as soy+wheat and soy+wheat+pea, proves to be beneficial in enhancing the quantity of protein and leading to balanced amino acid composition in certain formats of plant-based meat products, particularly chunks, kebabs, and patties. Sunflower oil, palm oil, soybean oil, and coconut oil are the predominant sources of fat in the plant-based meat products. Some plant-based egg products belonging to the powder and scrambled egg premix formats meet the criteria to be claimed as a 'source' of omega-3 fatty acids. Nevertheless, the plant-based products can continue to improve their PUFA and micronutrient content and reduce the levels of saturated fat and sodium through ingredient diversification and product reformulation efforts.

Recommendations to the plant-based food industry

The Indian plant-based smart protein sector can work towards improving their communication and marketing strategies to convey the nutritional advantages and claims of products to consumers, in line with the Labelling and Display Regulations of FSSAI[11]. The ingredient diversification endeavours could focus on exploring unconventional sources of plant protein with better amino acid composition, arriving at an optimal combination of plant protein blends, and formulating novel plant-based fat ingredients with superior fatty acid profiles. Product reformulation efforts must be evidence-based rather than trial-and-error in order to reduce the fat and sodium levels. Recent research investigations have revealed the potential of structuring plant-based proteins and fats to improve the protein functionality and reduce the lipidic ingredients of plant-based meat products. These proofs-of-concept should be transformed and scaled-up for commercial applications.

Recommendations to government funding bodies

Directing more funding toward R&D and innovation projects in the field of smart proteins (alternative proteins) can foster research in the following areas:

- New product development endeavours focusing on the nutritional parity of plant-based meat and egg products with their conventional counterparts without compromising on the taste and price.

- Ingredient optimisation, product reformulation efforts, and salt reduction approaches can pave the way for healthier plant-based meat and egg products.

- Leveraging India's indigenous crops such as pulses, legumes, millets, hemp, and other protein-rich crops promises to diversify the ingredient basket of the Indian plant-based smart protein industry. Identifying crop traits of interest for the development of plant-based products and breeding specialty crops using advanced approaches such as artificial intelligence (AI), and biofortification can lead to improved nutritional and functional quality of plant proteins.

- Micronutrient content is one of the areas that demands the plant-based sector's attention. The plant-based meat and egg products could be potential vehicles for delivering maximum micronutrient benefits to consumers. As the plant-based sector continues to evolve in India and as consumers increasingly adopt these products, plant-based meat and eggs have the potential to address some important nutritional needs that the whole plant sources might not be able to fulfil due to the presence of anti-nutrients. Currently, the lack of information, price and accessibility barriers, and high variance in micronutrient profiles of plant-based meat products are primary challenges. Upstream strategies such as biofortification (crop development and cultivation) and ingredient optimisation approaches (sprouting, enzymatic treatment, and controlled fermentation) can enhance micronutrient levels and improve their bioavailability in the plant-based meat and egg products.

- Novel structuring approaches such as microgelation and oleogelation to develop functional plant proteins and fats have the potential to reduce dependency on texturizing additives and improve the nutritional quality and application range of current lipid offerings, respectively.

- Comprehensive investigations on protein digestibility and nutrient bioavailability of plant-based alternatives to animal-derived products. Understanding the long-term influence of a plant-based diet on gut health and its role in mitigating lifestyle disorders would strengthen the scientific evidence underpinning the contribution of this product category to public health.

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About the Good Food Institute India

The Good Food Institute India (GFI India) is the central expert organisation, thought leader, and convening body in the Indian alternative protein or smart protein sector in India. As part of an international network of organisations with partners in the U.S., Brazil, Europe, Israel, and Asia Pacific, GFI India is on a mission to build a secure, sustainable, and just global food future. With unique insights across science, policy and industry we are using the power of food innovation and markets to accelerate the transition of our food system toward smart proteins. In building the sector from the ground up in India, we're aiming to establish a model for its growth all across the developing world.

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