Journal of Apitherapy and Nature/Apiterapi ve Doğa Dergisi, 6(2), 57-72, 2023
Review article/Derleme makalesi

Apiterapi ve Doğa Dergisi
Journal of Apitherapy and Nature
www.dergipark.gov.tr/jan

Plant-Based Foods and Latest Developments

Bitki Bazlı Gıdalar ve Güncel Gelişmeler

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Received/Geliş Tarihi: 28/10/2023

Accepted/ Kabul Tarihi: 19/12/2023

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Doi: 10.35206/jan.1382644

e-ISSN: 2667-4734

Abstract

In recent years, plant-based foods have been widely preferred due to their benefits to human health and economy, as well as their reduction of greenhouse gas emissions and their benefits to the environment. In order to meet the increasing need for plant protein, research has increased and different plant protein sources such as seaweed, spirulina, sugar beet leaves, alfalfa and hemp seeds have begun to be used in developed products. There are many studies on the benefits of an herbal diet, and many herbal products have been developed in recent years. However, most of the developed products have deficiencies in terms of appearance, texture, taste and nutritional value, and new methods need to be investigated to improve this situation. In addition, it would be wrong to say that all of the developed vegetable protein products are superior to animal sources in terms of nutritional value. In this review, plant protein sources were examined and studies on their health effects and bioavailability and the latest technological developments were evaluated.

Keywords: Plant-based foods, Plant-based proteins, Animal foods, Greenhouse gas, Sustainability

Özet

Bitki bazlı gıdalar son yıllarda insan sağlığına faydaları ve ekonomik olmalarının yanında sera gazı emisyonlarını azaltması, çevreye sağladığı yararlar sebebiyle de çok tercih edilmektedir. Bitkisel proteine artan ihtiyacı karşılamak için araştırmalar artmış ve deniz yosunu, spirulina, şeker pancarı yaprağı, yonca, kenevir tohumu gibi farklı bitkisel protein kaynakları da geliştirilen ürünlerde kullanılmaya başlanmıştır. Bitkisel beslenmeni yararlarına dair pek çok çalışma mevcuttur ve son yıllarda bitkisel kaynaklı pek çok ürün geliştirilmiştir. Fakat geliştirilen ürünlerin çoğunda görünüm, doku, lezzet ve besin değeri açısından eksikler vardır ve bu durumun iyileştirilmesi için yeni yöntemlerin araştırılması gerekmektedir. Ayrıca geliştirilen bitkisel protein ürünlerinin hepsinin besin değeri açısından hayvansal kaynaklardan üstün olduğunu söylemek yanlış olacaktır. Bu derlemede bitkisel protein kaynakları irdelenmiş

ve sağlık etkileri ve biyoyararlanımlarına dair çalışmalar ile son teknolojik gelişmeler değerlendirilmiştir.

Anahtar Kelimeler: Bitki bazlı gıdalar, Bitkisel proteinler, Hayvansal gıdalar, Sera gazı, Sürdürülebilirlik

1. INTRODUCTION

The world population is expected to reach 10 billion by 2050. Accordingly, the United Nations states that protein demand will double and if no precautions are taken, there will be a protein shortage (Aimutis, 2022). In terms of quantity, quality and sustainable supply, traditional protein production methods cannot meet the future needs of human life (Liu et al., 2023).

The human body consists of macronutrients (carbohydrates, protein, fat) and micronutrients (vitamins, minerals, water). Protein, a macronutrient, has functions in the body such as muscle building, cell repair and immune response control (Kumar et al., 2022; Nasrabadi et al., 2021).

In addition, the omnivorous diet that most people follow is harmful to the planet in terms of climate crisis, decrease in biodiversity and pollution.

However, a diet consuming vegetable proteins will reduce these negative effects and greenhouse gas emissions by up to 80% (Pye et al., 2022). At the same time, less agricultural land, water and energy are needed for the production of these proteins, and less greenhouse gas emissions occur compared to animal husbandry (Milião et al., 2022; Nasrabadi et al., 2021).

While the low-cost and sustainable production of plant-based protein attracts attention, many studies are trying to produce plant-based substitute meat. However, studies in this field need innovation and development. Products developed with synthetic biology technology create conditions for large-scale production of essential components in plant-based foods. The safety of technology and products must be ensured during the production process. Potential biosecurity risks need to be fully estimated in order to establish independent, objective technical systems for production safety or nutritional assessment. Taken together, combining existing technology with synthetic biology technology needs scientific support for the production of high-quality plant-based meat (Liu et al.,2023).

In this review, plant protein sources were examined and studies on their health effects and bioavailability and the latest technological developments were evaluated.

2. PLANT-BASED PROTEINS

Recently, plant proteins have been found attractive by consumers due to their more economical, sustainable and positive health effects compared to animal protein sources (Nasrabadi et al., 2021). However, despite this interest and the increased tendency to try new products compared to the past, individuals who have completely stopped consuming animal protein constitute 1% of society (Maciel et al., 2022).

Studies examining consumers' attitudes towards plant proteins have explained the reasons why individuals do not consume them as not having sufficient knowledge about these proteins and the products produced (Drolet-Labelle et al., 2023).

Some studies have revealed that individuals do not find products produced using plant protein sources healthy and do not want to consume them because they are artificial and overly processed.

In addition, there are some who find it unhealthy due to the high salt content used to enrich its taste. Most consumers think that vitamins and minerals such as iron and B12 found in animal meat are not found in any plant food, and therefore none of them can replace meat (Drolet-Labelle et al., 2023; Rizzo et al., 2023). In addition to those who defend the disadvantages of plant protein sources, there are those who state that they are more environmentally friendly and easily digestible compared to animal proteins, and that they feel lighter after consuming them (Drolet-Labelle et al., 2023).

When the distribution of consumers according to sociodemographic characteristics is examined; It has been revealed that women (Drolet-Labelle et al., 2023), individuals with higher education levels, and vegans or vegetarians are more willing to try alternative protein sources. Although there are studies arguing that age is not a factor, there are studies revealing that young people are more open to new tastes (Rizzo et al., 2023).

Cereals and pseudocereals such as wheat, corn, rice, sorghum, quinoa, buckwheat, amaranth; Legumes such as beans, peas, soybeans and oilseeds such as sesame, flaxseed, canola, pumpkin seeds, rapeseed and sunflower seeds can be given as examples of vegetable protein sources (Kumar et al., 2022). Apart from these, there are also different plant protein sources such as seaweed, spirulina, sugar beet leaves, alfalfa and hemp seeds.

2.1. Legumes and Oilseeds

When looking at the protein content of legumes, it is seen that broad beans are 30%, mung beans are 28%, lentils are 20-30%, and chickpeas are 18-25% (Webb et al., 2023). Among the oilseeds, sunflower seeds, flaxseeds, pumpkin seeds, sesame, almonds, cashews and canola contain 16-36% protein (Hoehnel et al., 2022).

2.2. Cereals and Pseudocereals

In a study examining the protein content of grains, it was revealed that oats contain 64% protein, brown rice 65%, wheat 81%, and potatoes and peas 80% (Kumar et al., 2022). Grains such as quinoa, buckwheat, chia and amaranth are called pseudocereals and contain 12-19% more protein than other grains. Its amino acid balance is better and it is rich in lysine (Hoehnel et al., 2022).

Chia seeds are very rich in dietary fiber. However, it contains less lysine compared to other pseudocereals (Hoehnel et al., 2022). Researchers state that chia seeds can be a good protein alternative in meat derivatives because their protein content is close to lentils, peas and chickpeas.

Buckwheat is poor in leucine and rich in lysine. Apart from this, it is gluten-free and is frequently used in the development of gluten-free products since it contains low amounts of prolamin. It is also less allergenic compared to other grains (Jin et al., 2022). Although the non-nutritive elements it contains, such as tannin, phytic acid and saponin, negatively affect the utilization of proteins, its bioavailability is higher than most grains and is 80%. Nowadays, methods such as fermentation, sprouting, and enzymatic hydrolysis are used to increase this rate (Jin et al., 2022).

2.3. Macro and Micro Algae

Macroalgae such as spirulina and seaweed; Microalgae such as Rhodomonas salina, Tetraselmis chui and Phaeodactylum tricornutum and duckweed are examined in this group (Coleman et al., 2022). A study has shown that microalgae Rhodomonas salina has a crab aroma, Phaeodactylum tricornutum has a mussel aroma, and Tetraselmis chui microalgae has crab and fish aromas, and these can be used as seafood alternatives (Coleman et al., 2022).

Seaweeds are known to have high calcium, magnesium, phosphorus, potassium, sodium and iron minerals. They have an umami taste, called the 5th taste, due to the aspartic and glutamic acids they contain. Recently, the consumption of seaweed-based food products

has increased significantly in the world due to this umami taste. It is also a prebiotic and has properties that regulate the intestinal microbiome (Raja et al., 2022). Seaweed is a food frequently consumed in Asian countries. It is even stated that mothers who have just given birth consume seaweed soup to provide protein, vitamin A and mineral support for both themselves and their babies (Torun & Konuklugil, 2020).

Seaweeds, called edible macroalgae, are divided into three groups: red (Rhodophyta), green (Chlorophyta) and brown (Ochrophyta, Phaeophyceae). Although the protein content of seaweeds varies depending on the type, it is around 30-50% and their bioavailability is 75%. When looking at the amino acid balance, it is seen that it is rich in phenylalanine, tyrosine and theronin amino acids, which are limited in plant proteins. But it is poor in methionine and lysine (Raja et al., 2022). The addition of seaweed to cheese improves its nutritional value and sensory properties by increasing the concentration of calcium it contains. There are studies showing that adding seaweed to probiotic yoghurt enriches the yoghurt in terms of calcium, potassium, sodium, magnesium and iron (Kandil, 2019).

When seaweed powder is added to ice cream, there is no change in the amount of fat but a significant increase in the amount of protein. This addition also makes the ice cream more creamy and delicious (Raja et al., 2022). The possibility of heavy metal deposits such as cadmium, arsenic, lead and copper in seaweed is a disadvantage of seaweed. Another disadvantage is that since they are rich in iodine, excessive consumption may cause disease effects (Raja et al., 2022).

2.4. Clover

Although alfalfa is an important protein source for cattle due to its nutrition, the World Health Organization (WHO) and the Food and Agriculture Organization (FAO) reported that the soluble and insoluble protein found in its leaves has a balanced amino acid composition and is an important source that can be used in human nutrition.

It is suggested by some researchers that clover can limit some diseases such as high cholesterol, diabetes, and atherosclerosis due to the antioxidants it contains (Hadidi et al., 2023).

2.5. Other Plant-based Protein Sources

The cactus called *Pereskia aculeata*, also known as the "flesh of the poor", found in Brazil and Florida state of the North American continent, has a very high protein content. Its protein content is 25%, higher than legumes. *Jatropha curcas* L. is a small tree species found in almost

all countries with tropical climates. Jatropha seed has high protein quality as it contains all essential amino acids except lysine.

Glutelin and globulin are the main components that make up the proteins of this plant. 60% of its protein consists of essential amino acids. In addition, lysine content constitutes 5-6% of the total protein content and can be used to enrich lysine-poor grain foods (Milião et al., 2022). The leaves of sugar beet, another source of vegetable protein, are rich in protein and contain 19.4-22.8% protein in their dry weight. It has a balanced amino acid composition consisting of leucine, valine, phenylalanine, lysine, theronin, isoleucine and methionine.

Although bamboo shoots vary depending on species and maturity, they have low fat, high protein, dietary fiber, vitamin and mineral content.

The variety with the highest protein amount is Yushania alpina, which contains 33.4% protein. It contains 17 types of amino acids, 8 of which are essential amino acids. Although it is poor in lysine, the most abundant amino acid is tyrosine (Milião et al., 2022).

Hemp seeds contain 25-30% protein and have high digestibility. Since it has a good balance of essential amino acids, it is a suitable ingredient for meat derivatives. It also contains arginine, which ensures normal blood pressure by ensuring vasodilation of the vessels (Milião et al., 2022).

3. HEALTH EFFECTS and BIOAVAILABILITY

Red meat is rich in nutrients such as fat, high-quality protein, minerals and multivitamins that the body needs to support growth and development. It especially contains 8 types of essential amino acids that the human body cannot synthesize. Therefore, compared to plant protein, animal protein has a higher biological potential. Although meat is rich in nutrients, attention should be paid to its health risks. Additionally, excessive consumption of processed red meat can lead to inflammatory bowel disease and functional gastrointestinal disorders. The World Cancer Research Fund/American Institute for Cancer Research reported that consumption of red meat and processed meat has a possible association with the risk of colon cancer (Zhao et al., 2018).

Cholesterol intake increases with animal-based nutrition, posing a problem for individuals with lactose intolerance or animal protein allergy (Aimutis, 2022). Diets rich in animal protein also have negative effects on the intestinal microbiota and fecal content (Gratz et al., 2020).

In plant-based nutrition, there are studies showing that high-quality plant protein consumption is associated with low mortality and reduces the risk of diverticulitis, cataract, heart failure, hypertension and cancer development (Brown, 2023; Herpich et al., 2022; Keaver et al., 2021; Key et al., 2022; Kumar et al., 2022; Neary et al., 2022; Shaghaghian et al., 2022). Again, since herbal nutrition improves glycemic control and reduces the risk of complications in individuals with Type II DM, the American Association of Clinical Endocrinologists recommends plant-based nutrition for individuals with Type II DM (Pye et al., 2022). In addition, since it has hypoallergenic properties, it is seen as a protein supplement for children and adults who are allergic to cow's milk (Kumar et al., 2022).

There are also studies showing the positive health effects of vegetable protein intake in individuals with chronic kidney failure (CKD) (Brown, 2023; Stanford et al., 2023). In a study including 5316 adults, it was observed that every 20 g increase of vegetable protein reduced the incidence of CKD by 16% (Herpich et al., 2022). In addition, since plant sources have high phytic acid, phosphorus bioavailability is low, which positively affects chronic renal failure (Burstad et al., 2023).

In a study investigating the effect of herbal nutrition on neurological and psychiatric disorders, an improvement in pain, anxiety, stress and depressive symptoms was observed (Herpich et al., 2022; Pye et al., 2022). Supporting this, in a study including 333 healthy participants between the ages of 8-79, it was found that positive mood was directly proportional to the herbal diet index score in children (Ma et al., 2023). However, studies on this subject are contradictory and more research is needed. Vegetable proteins also have positive effects on the feeling of fullness and muscle synthesis rate.

In a study involving 24 adult men to measure the satiety effect of vegetable minced meat, participants were called to two clinic appointments at least a week apart and were offered bolognese pasta containing vegetable minced meat or ground beef and asked to eat until they were full. As a result of the study, it was observed that participants reached saturation by consuming less plant-based bolognese pasta compared to ground beef, supporting the hypothesis (Muhlhausler et al., 2023).

In the study investigating the effects of vegetable proteins on the muscle formation mechanism, the participants, all of whom were 24 men, were divided into two groups and one group was given 230 g of vegetable meat containing 40 g of wheat and chickpea proteins, while

the other group was given 174 g of chicken breast to consume. At the end of the study, a similar muscle protein synthesis rate was observed in individuals consuming plant protein products as those consuming chicken (Kouw et al., 2022).

4. OVERVIEW of TECHNOLOGICAL DEVELOPMENTS and VEGETABLE PROTEIN SOURCES

Although plant proteins have positive health effects and are environmentally friendly, they also have some disadvantages such as having an unusual taste and difficult digestibility (Shaghaghian et al., 2022; Drolet-Labelle et al., 2023). However, today the food industry is trying to prevent these disadvantages by using various technological methods; herbal cheeses, meat, milk, etc. It produces alternatives to animal sources with similar taste and nutritional value (Maciel et al., 2022).

Various meat substitutes have been developed by the food industry from past to the present. These are divided into 1st and 2nd generation meat substitutes. 1st generation meat substitutes include products produced by cooking defatted soybean meal, soy protein concentrate or gluten at low moisture, and these products have a fibrous and spongy texture. Second generation meat substitutes are products obtained as a result of high moisture cooking and aim to imitate meat in terms of appearance, nutritional values, aroma and taste. New generation meat analogues can be cited as examples of 2nd generation meat substitutes (Penna Franca, 2022).

As a high-value food ingredient, fat contributes to many sensory qualities of meat products, such as physical appearance, taste, juiciness and chewiness. The use of oil imparts sensory as well as certain technological properties to the masses of food products. Therefore, the structure of fat in meat is important to improve the overall performance of plant-based meat (Liu et al., 2023).

Enzymes are known to improve the functional properties of proteins. However, high temperature and pressure; It is the most common processing technology to create fibrous meat structure.

However, high temperatures cause enzymes to denature and stop working. Therefore, it is necessary to improve the thermal stability of vegetable protein-based meat-related enzymes (such as glutamine transaminase and laccase) and obtain engineering enzymes that are heat resistant and have high enzyme activity. These modifications are grouped into 4 groups: physical, chemical, biological and other (amyloid fibrillization and complexity) (Liu et al.,

2023; Nasrabadi et al., 2021). Unlike animal products, plant-based meats are deficient in vitamins B2, B12, iodine, zinc, calcium, potassium, selenium and other nutrients (McClements & Grossmann, 2021). These deficiencies need to be eliminated in plant-based meats.

Proteins from plants such as soybeans, wheat, and peas are the main raw materials used in plant-based meat production. The amino acid composition of these plant protein sources does not meet nutritional requirements. In order for a plant-based meat product to be considered a well-balanced source of amino acids for human nutrition, plant protein and other proteins must be combined. Proteins such as algae protein and edible mushroom protein can be used for this.

The digestibility and bioavailability of plant protein is limited due to the presence of anti-nutritional factors. Phytic acid is commonly found in legumes, but the presence of phytic acid affects the absorption of minerals as well as proteins, so efforts should be made to reduce or eliminate phytic acid in plant-based meats (Şahin, 2023).

In a study conducted to reduce phytic acid content, Aspergillus sojae, Aspergillus ficuum were used and the effects of fermentation on antinutritional factors in lupine flour were examined. It was determined that the phytic acid content of lupine flour fermented with Aspergillus sojae and Aspergillus ficuum was significantly reduced. The use of Aspergillus ficuum showed the best effect and the phytic acid content decreased by 73% (Olukomaiya et al, 2020).

When looking at products developed other than meat substitutes; At the top is tempeh, which is made with soybeans and uses legumes and coconut waste in different parts of Asia. This product is considered a good source of positive effects on human health due to the high protein and isoflavonoids in soy. 100 g of fresh soybean tempeh contains 20.8 g protein, 13.5 g carbohydrates, 8.8 g fat and 234 mg potassium (Romulo & Surya, 2021).

In a study measuring the liking of cashew fiber on individuals, volunteers developed coxinha, mini burgers, kibbeh and sausages using cashew fiber and presented them to the participants. Participants also stated after the tasting that the use of cashew fiber in products developed as an alternative to minced meat, chicken, fish and crab would attract a lot of attention (Maciel et al., 2022).

In another study, hamburger patty alternatives were created using mycoprotein, soy, pea and insect protein and were examined in terms of their environmental impact, nutritional value and texture.

As a result of the study, meatballs made from peas and soy are more environmentally friendly; pea and insect protein patties are sensory better; It has been determined that soy and mycoprotein have higher nutritional value (Smetana et al., 2021). In another similar study, vegetable protein hamburger patties were developed using soy and pumpkin seed flour and revealed that these hamburger patties had 10 times less impact on the environment than meat-based patties (Baune et al., 2022). Again, herbal mayonnaises are produced using various products such as chia seed oil, peanut, sesame oil, chickpea aquafaba, pea and soybean extract (de Menezes et al., 2022).

Apart from these, soy protein is added to products such as bread and pasta to increase the water retention capacity and extend the shelf life; rice protein concentrate to improve nutritional value and cooking quality (Kumar et al., 2022), legumes and pseudocereals are added to prolong the feeling of fullness (Hoehnel et al., 2022). In plant-based meat production, wheat gluten and legume proteins are used due to their viscoelastic structure; Quinoa is also used as a binder, oil alternative and gelling agent (Shaghaghian et al., 2022). Plant-based meat production uses umami compounds such as glutamate, inosinate and guanylate to create meat taste. Legumes are one of the main sources of vegetable protein due to their high protein content and nutritional value.

The presence of undesirable tastes such as bean-like taste and grassy taste in legumes prevents the application and consumption of legume protein and products. There are some methods to eliminate or reduce the undesirable aroma. One method is to use a modification of the protein by controlled biological treatment. For example, fermentation is widely used to improve the palatability and nutritional value of plant proteins. The metabolic effects of strains in the fermentation process can contribute to the production of new aromatic compounds, some of the undesirable aroma compounds can be eliminated or their content can be reduced (Sajib et al., 2023).

One study found that fermentation of pea protein isolates using Lactobacillus casei reduced bitterness intensity after 48 h (Arteaga et al., 2021). However, there is a small amount of literature showing that fermentation leads to a significant reduction in bean aroma, which is the main odor of plant proteins. Therefore, a more in-depth investigation of the relevant ingredient is required to prevent the occurrence of off-flavors or to significantly reduce its content in order to increase consumers' acceptability of plant proteins. Adding spices for odor masking is used to mask off-flavors and make plant-based meats resemble the flavor of the original meat (Mittermeier-Kleßinger et al., 2021).

Natural spices like basil and fennel can flavor plant-based meats and mask other flavors. In addition, monosaccharides, amino acids, and aroma nucleotides, which are the precursors of the Maillard reaction, are added to plant-based meat products to ensure that the Maillard reaction occurs during the preparation and cooking process. Again, yeast extract, in addition to being resistant to high temperatures, can cause Maillard reactions with the amino compounds in the ingredients with reducing sugars in the ingredients under high-temperature cooking conditions, and the taste of the product can be closer to meat (Liu et al., 2023). It would be wrong to say that all of the developed plant protein sources are superior to animal sources in terms of nutritional value. In support of this, in a study in which vegetable cheeses were developed using products such as coconut oil, modified starch, modified potato starch, coconut cream and tapioca starch, it was found that the protein values of these cheeses were lower than traditional cheeses (Grasso et al., 2021).

Another study compared the nutritional value of plant-based meat alternatives in supermarkets in Ireland and the United Kingdom with traditional meat products and found that these products had a better nutritional profile than hamburger meat, sausages, and pork, but less so than ground beef, beef, and chicken breast. It has been found that it has a worse nutritional profile than processed meat products (Lindberg et al., 2022).

The development of the field of synthetic biology has allowed them to use cell engineering, which is important for plant-based meat. These engineering processes can transform important components of cells such as color, taste and flavor. It can help plant-based meats resemble real meat in terms of appearance characteristics (Shleikin & Medvedev, 2014).

Hemoglobin or myoglobin, the molecule that carries iron in animals, is responsible for the color and flavor of meat. Therefore, hemoglobin can be used as a functional food ingredient in meat analogues. Thanks to synthetic biology, cell factories that can synthesize hemoglobin have been designed. Thus, an alternative production method was created other than extraction from plant tissue or animal blood (Zhao et al., 2018). It is thought that in future studies, synthetic biology may help develop specific functional proteins that have water retention and fiber formation functions in meat (Liu et al., 2023).

5. CONCLUSION

Although plant-based foods are popular due to their benefits to human health and their economic and sustainability, they also have some disadvantages such as having an unusual taste and difficult digestibility. With the increase in people's health needs in recent years, plant-

based meat products have gradually come into the public interest. However, many plant-based meats available in limited quantities on the market today contain too many additives. These foods often contain high levels of sugar, salt or additives such as spices, coloring agents, emulsifiers and preservatives. Over-processing can turn original high-quality and healthy plant-based meat into ultra-processed foods. Therefore, more experimental research is still needed on how to control the degree of processing of plant-based meat products.

The sustainability of food systems is a global challenge due to the detrimental effects of food production on nitrogen and phosphorus cycling, biodiversity loss and climate change. This need has led to a shift in the food industry towards plant-based foods. There is a concern that plant-based foods may be nutritionally deficient, but they also have health-promoting benefits such as dietary fibers and nutraceuticals that are not found in most animal products.

The effects of long-term consumption of plant-derived meats on human health are not known today. Although recent studies have compared the digestibility and gastrointestinal digestion process of animal meats with plant-based meats in an in vitro digestion model, these results still have some limitations as the human body is a more complex environment.

Plant-based meat is a promising solution to partially alleviate meat supply problems. Improvements are needed in the texture, taste and nutrition of plant-based meats. However, there are deficiencies between plant-based meat and real meat in various aspects such as appearance, texture, taste, nutrition, and new methods need to be investigated to improve this situation.

In addition, countries may need to halt the expansion of agricultural land, reduce the number of livestock, introduce a meat tax and develop incentive schemes that support sustainable consumer products to mitigate climate change. A shift to predominantly plant-based diets and diversification of plant-based protein intake may be needed to protect human and environmental health. Much work, including sensory evaluation, will be needed in the future to develop targeted plant-based products that are tasty, affordable and healthy.

DECLARATIONS

The authors declare that they have no conflicts of interest.

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