



## Review article

# The state of plant-based food development and its prospects in the Indonesia market



Viviana Arwanto, Gisela Buschle-Diller, Yayon Pamula Mukti, Ardhia Deasy Rosita Dewi, Christina Mumpuni, Maria Goretti Marianti Purwanto, Johan Sukweenadhi\*

Faculty of Biotechnology, University of Surabaya, Raya Kalirungkut, Surabaya 60293, Indonesia

## ARTICLE INFO

## Keywords:

Alternative product  
Diet  
Plant-based

## ABSTRACT

Innovations in food biotechnology reflect the increasing demand for healthy food and the change in conventional dietary patterns to plant-based diets, encouraging the development of functional products and opening new perspectives for industry interests. In addition, the development of vegetable-based products is supported by several studies that state that plant-based diets help reduce the risk of diseases, reduce stress, and even help maintain healthy body weight, making this diet a promising development for the future. The industry mainly uses fermentation techniques to obtain plant-based foodstuffs. However, fermentation is just one method that can develop probiotic products. Other methods include high moisture extrusion cooking and applying shear cells, for instance, for developing vegetable meats. This article summarizes trends and shifts in eating preferences, the response of the respective industry, and the future potential of plant-based products.

## 1. Introduction

Functional foods can be natural foods or products with one or more specific ingredients that are good for the health and wellbeing of customers. These specific components can be added to food, enhanced, or modified under special conditions. The term functional food was coined in Japan in the mid-1980s, and the country was the first to develop a specific regulatory approval process for functional foods. Functional foods are classified into several categories, including probiotics, functional drinks, dietary fiber, fruits, and vegetables (Rani et al., 2018; Tur and Bibiloni, 2016; Aihara, 2014).

In recent years, food biotechnology innovation has increased by 28 percent per year to deliver new products with functional claims. The global market for functional food is expanding, but modern consumer preferences have also been a driving force in developing food products that improve health and reduce disease risk. Several vegetables and fruits suitable as basic ingredients for functional products open new perspectives with commercial interest (Di Cagno et al., 2016). In the functional food market, products targeting gut health have led research and development efforts, focusing on probiotic foods. Despite the lack of research substantiating the effect of fruit on the survival or activity of probiotics in the digestive system; probiotic foods with basic ingredients such as fruit are very appealing to consumers (Do Espírito Santo et al., 2011). In addition to being used as

ingredients in probiotic foods, can be processed into various other products, such as plant-based medicine, dietary supplements, and so on. Plants have been used therapeutically or as food supplements in various cultures for centuries. Plant includes a variety of secondary metabolites, mostly known as phytochemicals, which occur naturally and offer medicinal and nutritional advantages to the human body. Functional foods or nutraceuticals include medical plants and frequently ingested plants or plant products that have the extra advantage of boosting health or avoiding illnesses and giving nutrients to the body (Ahmed, 2020; Chandra et al., 2021; Marriott, 2000). Table 1 shows companies with great influence on the plant-based food market.

Vegetarians and vegans constitute a minority of the population in several nations, ranging from 1 to 3 percent in Australia and New Zealand to 3–9 percent in North America and Europe and 8.5 percent in Israel (Qian et al., 2019). In Indonesia, there are approximately 2 million vegetarians or vegans. Even though this is a small number for a country of 260 million people, veganism has grown in popularity among health-conscious Indonesians (The Jakarta Post, 2018). However, according to DuPont Nutrition and Bioscience and IPSOS, demand for plant-based products is expected to continuously increase over the next five years, especially in the Asia Pacific market. In China and Thailand, demand for these products will increase by 200% over the next 5 years, driven by consumers who care about health, taste, and sustainability. 36% of consumers in the Asia Pacific have

\* Corresponding author.

E-mail address: [sukwee@staff.ubaya.ac.id](mailto:sukwee@staff.ubaya.ac.id) (J. Sukweenadhi).

**Table 1.** Companies with major influence on the plant-based product market.

Company Name	Description	Product	Company Website
Beyond Meat	Offers innovative plant-based food products that are sold in over 65 countries around the world.	Vegan burger meat, meatballs, beef crumbles, sausages, chicken tenders, and jerky	<a href="https://www.beyondmeat.com/">https://www.beyondmeat.com/</a>
Impossible Foods	Developed plant-based burgers and sausages investing in research for imitating meat and other animal products.	Impossible burger and sausages	<a href="http://impossiblefoods.com/">http://impossiblefoods.com/</a>
Danone	This company sells plant-based dairy, essential dairy, specialized nutrition, and water. The company supplied its products in over 120 countries through a network of 530 research and innovation personnel spread over 40 nations.	Plant-based yogurt and cream, dessert and ice cream, nut and soy-based drink, coffee creamer, and protein milk	<a href="https://www.danone.com/">https://www.danone.com/</a>
Gardein	The company provides dairy- and meat-free products made from soy, wheat, and pea proteins, as well as vegetables and ancient grains in North America and Europe.	Chicken (burger patty, tender, and meat), meatballs, pork, beef (burger patty and ground), fish filet, etc	<a href="https://www.gardein.com/">https://www.gardein.com/</a>
Hain Celestial	The business provides various plant-based products, as well as meat substitutes. These goods are sold in more than 70 countries under various brands and distribution methods.	Alternatives to milk, sauces, grain cakes, coffee & tea, sweets, vegan yogurt alternatives, and meat (patty, sausage, ground meat)	<a href="https://www.hain.com/">https://www.hain.com/</a>
Amy's Kitchen, Inc.	More than 250 organic goods in 27 different categories are produced by the business, all of which are organic, non-GMO convenience, and frozen meals. Products are distributed throughout Latin America, South Asia, Australia, China, the United States, Canada, and other nations in the United Kingdom.	Bowl, veggie burger, pizza, burritos, wrap, chili, snacks, soup, and candy	<a href="https://www.amys.com/">https://www.amys.com/</a>
Daiya Foods Inc.	The firm is involved in the production and distribution of plant-based food items, such as dressings, cheese substitutes, yogurt substitutes, and desserts. The firm is geographically present throughout North America, Latin America, Europe, and the Asia-Pacific region.	Cheeze, gluten-free pizza, vegetable crust pizza, dessert, burritos, sauce, etc.	<a href="https://daiyafoods.com/">https://daiyafoods.com/</a>
Nestlé S.A.	Through twenty-nine of its brands, Nestlé is involved in the production and distribution of food, beverages, and nutritional items. In the plant-based food industry, the business primarily provides plant-based meat, dairy alternatives, seafood alternatives, egg replacers, and plant-based confectionary. The product is sold all over the world, with the majority of sales occurring in North America, Europe, Asia-Pacific, the Middle East, and Africa.	Milk alternative, chocolate malt beverage, plant-based product (egg, tuna, shrimp, burger patty, chicken, sausage, hotdogs), coffee latte, chocolate wafer, vegan condensed milk, and non-dairy creamer	<a href="https://www.nestle.com/">https://www.nestle.com/</a>
Unilever PLC	The business's Foods and Refreshment division sells items made from plant-based ingredients. Some of the company's subsidiaries, such as The Vegetarian Butcher and 3F Bio Ltd, sell plant-based goods, such as plant-based meat, ice cream, and other dishes. The business is geographically present throughout Asia-Pacific, Europe, North America, Latin America, the Middle East, and Africa.	Vegan dressings (mayo), non-dairy and vegan ice cream, vegan burger patty, vegan sandwich and pizza	<a href="https://www.unilever.com/">https://www.unilever.com/</a>

**Other mentioned companies:**

Plamil Foods Ltd. (U.K.), Sanitarium Health and Wellbeing Company (Australia), Sahmyook Foods (South Korea), Axiom Foods (U.S.), Lightlife Foods, Inc. (U.S.), Earth's Own Food Company Inc. (Canada), Taifun -Tofu GmbH (Germany), Marlow Foods Ltd. (U.K.), VBite Food Ltd (U.K.), Atlantic Natural Foods LLC (U.S.), and Nutrisoy Pty Ltd. (Australia).

(Modified from source: [Meticulous Market Research, 2021.](#))

changed to a low or no meat diet, while 78% of consumers believe that the intake of plant-based meat will continue to grow in the future (Oei, 2020). According to Putri et al. (2018), the demand for vegetables and fruits taken as a supplement to staple meals will continue to fluctuate with Indonesia's population growth, which is increasing yearly. Vegetable consumption per capita grew significantly in 2015 and 2016. Statistical data from 2015 show that the Indonesian population consumed 90.15 kg per capita of vegetables, which increased to 92.13 kg per capita in 2016. Fruit consumption fluctuated; according to national fruit consumption data each year, there is a decrease in fruit consumption that is inversely connected to population increase. However, when each product is analyzed individually, there is a large increase in produce consumption from 2015 to 2016.

## 2. Food trends

### 2.1. Diet tendency

Food preparation has always been a popular topic of discussion among the general population. As the oldest medical text, the Abers

Papyrus, presents the recipe for wheat germ and okra as an anti-diabetic diet, food preferences and remedies have an ancient historic origin (Marcus, 2013). The desire to lose weight by a specific diet has been documented since the nineteenth century, when arsenic pills claimed to speed up metabolism, among other bizarre regimes such as consuming tapeworms to prevent weight gain and Lord Byron's Vinegar and Water Diet (Mitrofanova, 2020). Over time, more types of diets became popular among the public to reduce weight or keep the body in ideal shape.

In the modern era, people see the importance of improving health to reduce the risk of health conditions related to diet, including chronic diseases. Some countries, such as Australia and the United Kingdom, published Dietary Guidelines for healthy eating based on available scientific evidence. However, many people do not follow these standards because they believe the available dietary advice is complicated (Ramachandran et al., 2018). This is further exacerbated by conflicting and ever-changing nutritional information. Figure 1 depicts information on online health data searches.

Over the past few years, food consumption patterns have drastically changed because of an aging population, increased awareness to live

healthier, and people's desire to globally reduce meat consumption. According to research by Pot et al. (2015), in the United Kingdom, consumption of whole milk, white bread, meat oils, and fats, as well as meat products, coffee, alcoholic beverages, sugar, sweets, and preservatives decreased while consumption of whole wheat and bread, fish, semi-skimmed milk, and fruit and vegetables increased significantly. These changes reflect a shift towards healthier eating patterns caused by the adherence to dietary recommendations or the awareness of an aging population and are facilitated by the broader availability of healthier foods (Pot et al., 2015).

## 2.2. Plant-based diet

A plant-based diet or plant-rich diet is a diet that uses plants as the major component of its food, thus replacing foods derived from animals or of synthetic origin. Although this diet avoids or minimizes animal products, it does not fall into the vegan category. A plant-based diet is a way of eating that emphasizes plant foods on your plate. This eating style is not intended to be restrictive. People who eat plant-based diets primarily may consume small amounts of meat, poultry, fish, seafood, and dairy (also known as semi-vegetarian, flexitarian, or pescatarian). For various reasons, some people who follow a plant-based diet may avoid eating meat and animal products altogether. A vegan diet eliminates all meat and animal products (dairy, eggs, fish, meat, poultry, and seafood), whereas a vegetarian diet only eliminates fish, meat, poultry, and seafood. However, there are a few vegetarian diet variations depend on whether particular items are eaten or avoided (Hemler and Hu, 2019; Summerfield, 2012).

Plant-based products are not only sought after and consumed by vegan or vegetarian consumers but also by consumers who want a healthier diet or follow a flexible lifestyle. According to a 2020 International Food Information Council (IFIC) survey, three out of every ten respondents have never tasted plant-based meat and dairy alternatives. However, the same survey discovered that the public view of animal protein health has improved since 2019 (O'Donnell, 2020). Despite the challenges associated with plant-based foodstuffs, these products have prompted the development of a booming industry. The shift to plant-based diets is spurring the aspirations of consumers with a different ideology and an increasing vegan population (Meticulous Market Research, 2021), as well as business investment in plant-based product manufacturers (Chandra et al., 2021). Research and development followed by the launch of new products by vegetable producers in developing countries such as Asia Pacific, Africa, Latin America, and the Middle East provide many opportunities for producers in the global vegetable product marketplace. However, certain meat replacements are more expensive, and customer preferences for soy and gluten-free goods have somewhat slowed industry growth (Meticulous Market Research, 2021).

In Indonesia, the interest in plant-based food is increasing quickly. As revealed in *The Global Vegetarian Index* published by Oliver's Travel, Indonesia is considered one of the best countries to enjoy vegetarian food; the country is ranked 16th out of the 20 highest countries in *Vegetarian-Friendly Countries* (Oliver's Travels, 2017). In the same article, it stated that one of the comparison methods for this ranking is the

number of restaurants that are vegetarian friendly, which shows that Indonesia has quite a lot of markets that can be entered by plant-based product industries and can support people willing to switch to a plant-based diet. The number of vegetarians registered with the Indonesia Vegetarian Society (IVS) in 2007 was 60 thousand and increased to 500 thousand in 2010. In addition, the survey showed that 90% of Indonesians began trying to consume more healthy food menus to increase body immunity (Meticulous Market Research, 2021; van der Laarse, 2015). Indonesia's rising number of vegetarians is partly attributable to the country's growing Buddhist and Hindu populations.

Nonetheless, as incomes improve, Indonesians consume more meat, causing meat the second-fastest-growing consumer food category from 2012 to 2017. Furthermore, due to easy access to health information online, health consciousness is growing among Indonesian consumers. In response to this trend, many vegetarian meat analog products have hit the Indonesian market in recent years (Wan, 2018). According to the Rakuten Insight study (Rakuten Insight, 2022), 86% of Indonesia respondents used plant-based milk, 49% dairy product substitutes, 43% plant-based meat alternatives, 27% plant-based sauces, 19% egg substitutes or vegan "eggs", and 5% other goods.

Indonesia's plant-based business is still in its early stages, with only a few businesses in the country offering vegan items. Green Butcher, a company that makes chicken and beef replacements, is a notable exception. Meatless Kingdom, for example, is predicted to grow swiftly due to high demand and limited competition. The plant-based food trend inspired an Indonesian start-up business, Meatless Kingdom, formed in 2019 by Widya Putra to develop an alternative to imported plant-based meat. Products include nuggets, sausages, Japanese dumplings (steamed dumplings), and others. Their products have been sent to Hong Kong, Taiwan, and Singapore, and a B2B (Business to Business) relationship is planned for 2022 (Vegonomist, 2022).

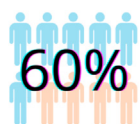
## 3. Processing of plant-based food

### 3.1. Minimally processed food

Vegetables and fruits are perishable commodities that incur significant postharvest losses due to a lack of preservation methods, particularly in low-income nations. Vegetables and fruits include a variety of vital components such as vitamins, fibers, and micronutrients that provide health advantages when ingested in sufficient quantities. Appearance, freshness, and color are the most commonly used criteria to evaluate "farm-to-fork" characteristics of fresh vegetables and fruits in order to signal quality along the supply chain (Sucheta et al., 2020). Many scientific and extension reports link the use of probiotic products to favorable effects on human health. Following this trend, minimally processed goods such as fresh-cut vegetables and fruits could be a viable vector for incorporating probiotics. Lactic acid bacteria can be found on fruit matrices such as apples, carrot slices and cantaloupe melons (Dávila-Aviña et al., 2020).

'Freshly cut' refers to any fruit or vegetable that has been physically manipulated from its original form to produce an edible product that is then packed and kept refrigerated. On average, minimally processed (MP) fruits and veggies decay faster than their fresh/intact counterparts. Understanding the physiological and microbiological changes that may occur during and after handling, processing, and storage is critical to selecting the appropriate procedures (Alzamora et al., 2016).

The temperature during storage, for example, is a crucial aspect to consider. Probiotics must be stored at 4–5 °C without compromising the product's sensory qualities through gradual fermentation. This criterion appears to be met in the case of fresh-cut fruit and vegetables (FCFVs). The possibility of microbial contamination on FCFVs cannot be excluded due to the processes involved in their manufacture. The surface of the fruit or vegetable itself may have a raised moisture content and nutritional availability, which is compatible with microbiota growth and favors its establishment. Customers are increasingly seeking natural food



Adults access health information online in US

The search for nutritional information increased by 32.7 percent between 1995 and 2012.

**Figure 1.** Access health information online (Pot et al., 2015; Ramachandran et al., 2018).

**Table 2.** Some examples of plant-based fermented products.

Fermentation Products	Basic Ingredients	Microorganisms Playing a Role
Yogurt	Vegetable milk	<i>Lactobacillus</i> sp.
Kimchi	Green onion, Chinese cabbage, red paper powder, radish, garlic, fermented seafood ( <i>jeotgal</i> ), and ginger	<i>Lactobacillus sakei</i> , <i>Leuconostoc mesenteroides</i> , <i>Lactobacillus plantarum</i> , <i>Leuconostoc citreum</i> , and other types of microbes.
Natto	Soybeans	<i>Bacillus subtilis</i> var. <i>natto</i>
Fermented fruits or vegetables	Pineapple	<i>Lactobacillus plantarum</i> and <i>Lactobacillus rossiae</i>
	Marrows, French beans, or Carrots	<i>Lactobacillus plantarum</i> , <i>Pediococcus pentosaceus</i> , and <i>Leuconostoc mesenteroides</i>
Sauerkraut	White cabbage	In the first phase, <i>Leuconostoc</i> spp. and <i>Weissella</i> spp. were present, followed by <i>Lactococcus lactis</i> and <i>Pediococcus</i> spp. in subsequent phase, and <i>Lactobacillus plantarum</i> in the last phase.
Fermented seeds	<i>Citrullus vulgaris</i> seeds, <i>Parkia biglobosa</i> seeds, soybeans, <i>Prosopis africana</i> seeds	<i>Bacillus</i> spp.
Pickled	Lemon	<i>Candida parapsilosis</i> and <i>Saccharomycetales</i>
Shalgam	Bulgur flour, sourdough, water, salt, turnip, purple carrot, and sometimes red beet are used.	<i>Lactobacillus paracasei</i> subsp. <i>paracasei</i> , <i>Lactobacillus plantarum</i> , <i>Lactobacillus brevis</i> , <i>Lactobacillus fermentum</i> , and <i>Saccharomyces cerevisiae</i> which play a role in forming the taste
Stinky tofu	Vegetables such as <i>spiny amaranth</i> , bamboo shoot, and winter melon	<i>Enterococcus</i> sp., <i>Bacillus</i> sp., <i>Streptococcus</i> sp., and <i>Lactobacillus</i> sp.
Zha cai or Chinese pickled vegetable	Knobby, fist-sized, swollen green steam from <i>Brassica juncea</i> subspecies <i>tatsai</i> .	<i>Lactobacillus plantarum</i>

(Source: Di Cagno et al., 2016; Patra et al., 2016; Chang et al., 2001; Gao et al., 2021.)

products that are not processed and free of synthetic antibacterial agents, due to concerns that such compounds may harm human health (Dávila-Aviña et al., 2020).

MP foods are unquestionably a rising sector of the retail food market. Widespread commercial utilization will necessitate a better understanding of microbial behavior at the physiological and molecular levels, the accessibility of systematic kinetic information on the impact on quality characteristics (with a focus on dosages and the influence of critical process factors), and technology optimization (Alzamora et al., 2016).

### 3.2. Fermented products

Fermenting is usually carried out by a consortium of microbes, which can bring about significant changes to the properties of the original food. Changes in food ingredients can consist of compounds that help improve general health, provide biogenic effects, or change the bioavailability of certain food elements. Fermentation can cause an increase in the concentration of amino acids or vitamins, induce bioavailability of phytochemicals and minerals, and improve the nutritional quality of food by easing the absorption of nutrients in the body (Di Cagno et al., 2016).

Fermented vegetables and fruits are associated with several social and cultural aspects in different communities and countries. The high nutritional value of fermented food makes it a common fare consumed worldwide. Traditional fermented foods such as *Kimchi* from Korea, *Natto* from Japan, and *Sauerkraut* from Germany are widely enjoyed in European countries and the United States (Di Cagno et al., 2016).

Vegetables and fruits are commonly used as ingredients in the fermentation process to bring about several types of products such as milk that can be used to develop further into other products such as yogurt and other fermented products. Soybeans, cereals, and nuts are some of the ingredients that are commonly used, but flax, sunflower seeds, and tubers can also be used. The processing is similar to making yogurt and encompasses conditioning milk for optimal growth of starter, inoculation, and incubation procedures, followed by cooling to 4 °C (Di Cagno et al., 2016).

The most popular vegetable milk is obtained from soybeans. It has great potential as a national food because it plays an important role in preventing several chronic degenerative diseases, is low in cholesterol and saturated fat, and contains a high content of dietary fiber, protein and amino acids, vitamin K, riboflavin, thiamine, magnesium, phosphorus, folic acid, isoflavone, and flavonoids. The low concentration of carbohydrates in soy milk can limit the growth and acidification by lactic

acid bacteria; thus, the addition of glucose or fructose is needed (O'Donnell, 2020).

Besides popular yogurt-like products, traditional fermented food components from other nations are commonly accessible, such as *Kimchi* (from Korea), a classic Korean side dish of salted and fermented vegetables, such as napa cabbage and Korean radish. *Natto*, a traditional Japanese meal prepared from whole soybeans fermented with *Bacillus subtilis* var. *natto*, is frequently eaten for breakfast and frequently accompanied by rice; A traditional Indonesian food called *Tempe* is created from fermented soybeans through a regulated natural fermentation process that binds the beans into a cake form; as well as Stinky Tofu and *Zha Cai* from China (see Table 2). The public favors a wide variety of fermented products, not only due to their nutritional value but also the reason of their taste when processed by fermentation (Di Cagno et al., 2016; Gao et al., 2021).

### 3.3. Plant-based meat substitutes

Plant-based meat is a product that mimics animal meat in its organoleptic properties; however, it is created by one or a combination of alternative proteinic ingredients. Alternative proteins are defined as ingredients derived from non-animal sources, although not all non-animal sources are plant-related or all of their composition consists of protein. In terms of production, infrastructure, and cost, natural sources of raw materials that can be exploited are divided into three: plants, microbial cells (included when used as hosts for the production of recombinant proteins), and animal cell cultures. In the case of formulating plant-based meat, animal sources of raw materials are excluded (Kinney et al., 2019).

Over the past few decades, sales of plant-based meat as a food ingredient have increased, as 44% of North American consumers prioritize reducing their overall meat consumption and adding more plant-based foods to their diet. One way to achieve the protein transition from animal to plant is by offering consumers a plant-based meat alternative. Consumers who favor meat will prefer products that are very similar in taste and texture to the real meat, thus encouraging the development of plant-based meat substitutes and the respective production technology. Technologies currently known to produce fibrous structures such as in meat are electro-spinning, high-moisture extrusion cooking (HMEC), and shear cell technology with the extrusion method, as shown in Figure 2 (Cornet et al., 2021).

Processing raw materials into vegetable meat uses extrusion technology which converts the original material into a continuous semi-solid

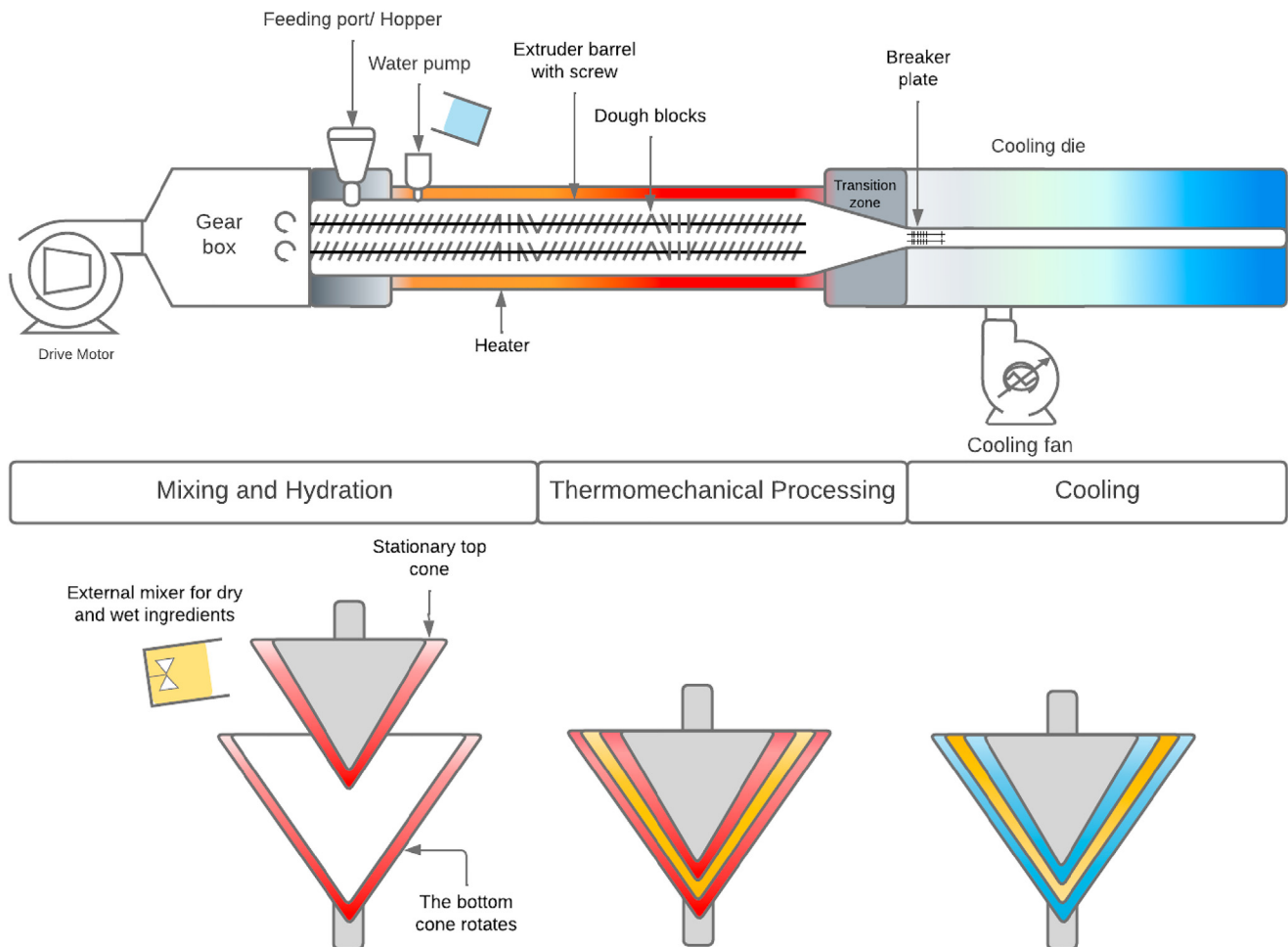


Figure 2. A systematic illustration of an extruder and a conical shear cell (modified from Cornet et al., 2021).

using heat, pressure, and moisture. This technology is also commonly employed in producing cereals, snacks, pasta, and other types of food. In products, this type of meat can be divided into two categories: whole muscle plant-based meat and restructured meat (Kinney et al., 2019).

The creation of entire muscle plant-based meat that resembles animal meat has a fibrous texture similar to striated muscle. The goal of this product's creation is to mimic the organoleptic properties of muscle, like those found in cuts of beef or pork, steak, and chicken breast, by utilizing Textured Vegetable Protein (TVP) in dry or wet form. The form is chosen based on the requirements of the company producing the product. In general, whole muscle plant-based meat production consists of six phases, as illustrated in Figure 3.

Besides whole muscle plant-based meat, the development of restructured plant-based meat products also gained importance. Special interest in products similar to animal meat that is ground, grated, or tied, and usually shaped into patties, balls, nuggets, and sausages. For these products, the processing is similar to whole muscle plant-based meat, where the TVP is used in dry form Kinney et al. (2019).

Shear cells were initially employed as an off-line approach to examine the influence of extrusion conditions on biopolymers, but with the processing of potassium caseinate in fibrillar form, this method became a new technology. Unlike HMEC, this technique employs good shear flow during heating. This process uses the same procedures as HMEC: mixing and hydration, thermo-mechanical treatment, and chilling. However, there is a significant difference between these two methods: HMEC is a continuous operation, whereas using shear cells is a batch process (Cornet et al., 2021).

#### 4. Impact of plant-based foods consumption on health and well-being

Vegetarianism has long been connected with faiths that preach respect for all living beings and adhere to nonviolent values. Several health benefits related to a reduction in meat-eating have been documented by research in the twentieth and twenty-first centuries. Worldwide, attracting an increasing number of adherents. Adopting a vegetarian diet might be motivated by a variety of factors. The major reasons are ethical considerations, which are based on the concept that slaughtering animals for human use is ethically wrong. Another compelling reason is health and the possible benefits of vegetarianism. Vegetarian diets, as long as they are adequately planned, are nutritionally adequate for all phases of life, according to the Academy of Nutrition and Dietetics (Hargreaves et al., 2021; *Becoming a vegetarian*, 2022).

The interest in plant-based diets, such as vegetarianism and veganism, will continue to increase, given that the trend of healthy plant-based foods is growing exponentially and is expected to persist for the years to come. In their research, Medawar et al. (2019) revealed that plant-based diets demonstrated short-to-moderately favorable effects on body weight, energy metabolism, and systemic inflammation in healthy, obese, and type 2 diabetes people compared to conventional diets. The study found that plant-based diets might alter the gut microbiome, resulting in a broad array of beneficial bacterial species. However, this research has not addressed the effects of this diet on brain health and cognitive function and the underlying mechanisms.

# Developing Whole Muscle Plant-Based Meat

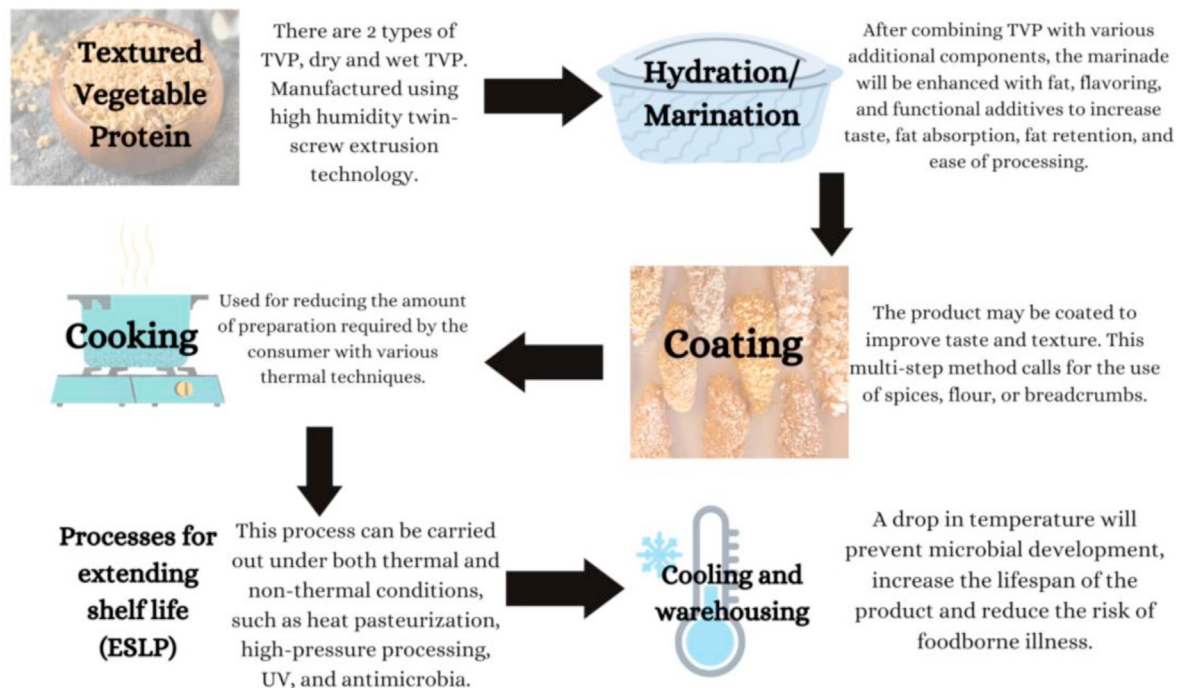


Figure 3. Steps for developing whole muscle plant-based meat (modified from Kinney et al., 2019).

A plant-based diet can potentially prevent or manage several chronic diseases such as type 2 diabetes, cardiovascular disease, and cancer. Clinical trials and observational studies have shown potential mechanisms that explain the association of this diet with type 2 diabetes, in which plant foods, individually or together, could improve insulin sensitivity and blood pressure, reduce long-term weight gain, and diminish inflammation in the pathway. Furthermore, plant-based diets have been linked to greater mental and physical health, a lower risk of depression, a higher quality of life, and overall health (Qian et al., 2019).

*Kimchi* is Korea's most popular traditional fermented meal and is also popular in other East Asian nations such as Japan and China. *Kimchi* is a group of probiotic lactic acid bacteria (LAB) fermented vegetable foods. The health benefits and quality of *kimchi* can be increased by manipulating the kinds and amounts of ingredients and fermentation conditions. *Kimchi* LAB is said to have anti-obesity, antimutagenic and anticancer effects, anti-atherosclerotic, and immunity-potentiating functions. It has been established that the fermentation process and the use of various salts may reduce or eliminate the detrimental effects of salt. *Kimchi* is a low-calorie meal with high quantities of vitamins (vitamin B complex, vitamin C, b-carotene, and more), minerals (Ca, K, Na, Fe, and P), and dietary fiber (24 percent on a dry basis). The major active components present in *kimchi* include phytochemicals such as b-sitosterol, benzyl isothiocyanate, indole compounds, and thiocyanate, which have been shown to have different therapeutic potential effects such as anti-obesity, anti-cancer, antioxidant, and anti-atherosclerotic activities. *Kimchi*-isolated LAB contains probiotic bacteria with a variety of health properties. Bacteria can be termed probiotic if they have one or more functional characteristics that benefit the gastrointestinal system. It has been demonstrated that probiotic microorganisms can survive the transit through the human GI tract and colonize the human large intestine. They can also boost the host's immune system and reduce inflammatory or allergic responses. LAB may generate beneficial organic acids during vegetable fermentation. They also generate ethanol, diacetyl, CO<sub>2</sub>, H<sub>2</sub>O<sub>2</sub>, and bacteriocins, all of which have antibacterial properties (Patra et al., 2016; Park et al., 2014).

*Natto* is an acquired taste, owing to its distinct aroma and texture. It has a strong, bitter flavor, and the ammonia odor may remind some people of old socks and cheese. The feel is similar to that of a mushy, stringy, and sticky tiny bean, which contributes to its unpleasant character. *Natto* contains vitamin K, which promotes bone health and has been linked to a decreased risk of heart disease and arterial calcification. It also contains nattokinase, which treats cancer, heart disease, high blood pressure, chronic rhinosinusitis, stroke, fibromyalgia, and other diseases. *Natto* improves intestinal health and aids in the treatment of diarrhea and lowers cholesterol (Chen et al., 2018; Link, 2018). In *Natto*, Sumi et al. (1987) discovered a strong fibrinolytic enzyme (nattokinase). This research investigated the possibility of employing nattokinase as a natural drug for oral fibrinolytic therapy. Numerous studies have found that *natto* inhibits intimal thickening and that a *natto* diet improves the fibrinolytic system and lessens thrombolytic effects. Recent research by Kim et al. (2008) adds to the body of data supporting the use of nattokinase supplements to prevent and treat hypertension.

*Sauerkraut* is one of the most popular and oldest types of preserved cabbage. It is created through malolactic fermentation and may be traced back to the 4th century BC as a dietary source. *Sauerkraut* is high in lactic acid, vitamins A, B, C, and K, and minerals, yet low in calories (approximately 80 kJ/100g). *Sauerkraut* includes a high concentration of chemicals that have been demonstrated to lower DNA damage and cell mutation rate in cancer patients. The concentration of these chemicals is highly dependent on the cabbage's fermentation conditions. The level of ascorbic acid was found to be greater in cabbage grown in the summer, with fermentation lowering the quantity. Inhibiting enzymatic markers in the liver may not be considered a sign of anticarcinogenic efficacy.

In comparison to indole-3-carbinol (I3C) and 3,3'-diindolylmethane, *sauerkraut* juice had a significant influence on the expression profile of essential enzymes on the estrogen metabolism in human breast cell lines (DIM). *Sauerkraut* has a lot of tyramine and glucosinolates, but it also includes a lot of histamines. Food histamine has been considered a key cause of food intolerance. Allergy responses are associated with histamine release; high consumption may lead to allergic symptoms. The

increased histamine load must be considered, especially during the peak season for persons suffering from hay fever. A dermatological study conducted in 1968 discovered false-positive scratch test findings owing to urticarial responses of some brands of *sauerkraut* because of their high histamine level (Shahbazi et al., 2021; Raak et al., 2014).

*Shalgam* is a probiotic food that is also high in nutrients. It aids in the regulation of the digestive system's pH. The calcium, potassium, and iron in *shalgam* help to build bones and teeth. Turnip contains cancer-fighting glucosinolates. Vitamin C has been shown to improve bone health and increase iron absorption in the body. The potassium level in turnips is high (1.91 g/kg). Potassium is extremely beneficial for cardiovascular health. Black carrots have more antioxidant vitamins, carotenoids, and phenolics than white carrots. Anthocyanins have antioxidant and anticancer capabilities in addition to their coloring characteristics. They soothe the nerves and stomach and improve liver function since they include group B vitamins (Baschali et al., 2017; Coskun, 2017).

Stinky tofu is a well-known and popular Taiwanese or Chinese fermented food. It is made by soaking tofu in a stinking brine that has been developed by combining several natural raw components. Stinky tofu is a food that includes the aglycon type of equol, which was discovered in adequate quantities for the first time in food. The process of equol formation in stinky tofu is unknown. However, certain live bacteria from additions or the fermentation environment may be responsible for equol formation. S-equol (40,7-dihydroxy-isoflavandiol) is an isoflavone daidzein gut bacterial metabolite. S-equol at 10 mg/day has provided considerable health benefits, including relief of menopausal symptoms and bone resorption. Women who excreted more than 1.2 mg equol daily had lower menopausal symptom ratings. In urine, 67% of the consumed stinky tofu was retrieved, indicating quick and substantial absorption (Jou et al., 2013; Abiru et al., 2012).

The benefits of a plant-based diet have also been demonstrated in the study of Dinu et al. (2017), which showed that vegetarians and vegans had a significantly lower level of relevant risk factors for chronic disease compared to non-vegans and non-vegetarians. In vegetarians, a marked reduction in the risk of ischemic heart events (lowered by 25%) and total cancer incidence (lowered by 8%) was observed. In his examination of the vegetarian diet, Garbett et al. (2016) pointed out that a vegetarian diet was related to a considerable reduction in blood pressure compared to a non-vegetarian diet. They developed various rationalizations that may be associated with a vegetarian diet and hypertension, such as a lower rate of cigarette use, a tendency to drink less alcohol, a lower mean BMI, and a higher preference for exercise compared to non-vegetarians.

## 5. Conclusion

Changes in society's dietary trends occur rapidly like tendencies in fashion and are driven by various variables including awareness of a healthy, sustainable lifestyle and a desire for a better diet. This paper explores the enormous potential of plant-based alternative foods and their successful rise in consumer preferences. With the understanding that vegetarians and vegans seem to dwell in health, the trend towards a plant-based diet is rapidly growing. This increase in plant consumption offers businesses in the food sector fresh opportunities to develop innovative plant-based products that are unique and have the potential to meet customer expectations. In addition, small business ventures, such as family restaurant chains focusing on serving vegetarian-friendly meals and fledgling start-up companies, might be supported in their endeavors. Although originally plant-based foods were mainly consumed by vegans and vegetarians, many people are now starting to develop a preference for these types of foods. This is driven by their nutritional content and unique concepts adopted by the respective manufacturing industry. Well-established fermented products are quite popular with the public, not only due to the advantageous fermentation process but also because of their health benefits and great taste. Novel processing methods, such as shear cell or high-moisture extrusion technologies, add flexibility and breadth, especially to the product range in the alternative meat sector.

Plant-based ingredients can now be the foundation of foods that resemble processed meats such as sausages or burgers in taste and texture. Protein replacement in dairy products opens up a venue for a large selection of highly nutritious choices. Adaptation of plant-based processed foods stimulates public curiosity about new food models, where these foods are designed to have organoleptic properties similar to well-known conventional products. Thus, it is unsurprising that plant-based alternatives have gained such importance in recent years.

## Declarations

### Author contribution statement

All authors listed have significantly contributed to the development and the writing of this article.

### Funding statement

This work was supported by Ministry of Education, Culture, Research and Technology, Republic of Indonesia (155/E1.1/KS.06.02/2022 and 004/SP2H/PT-L/LL7/2022).

### Data availability statement

Data included in article/supp. material/referenced in article.

### Declaration of interest's statement

The authors declare no conflict of interest.

### Additional information

No additional information is available for this paper.

## References

- Abiru, Y., Kumemura, M., Ueno, T., Uchiyama, S., Masaki, K., 2012. Discovery of an S-equol rich food stinky tofu, a traditional fermented soy product in Taiwan. *Int. J. Food Sci. Nutr.* 63 (8), 964–970.
- Ahmed, M.N., 2020. Medicinal Plant-based Functional Foods for the Management of Neurological Health. Preprints 2020, 2020060311.
- Aihara, K., 2014. Functional foods. *Encycl. Meat Sci.* 2, 32–36.
- Alzamora, S.M., López-Malo, A., Tapia, M.S., Welti-Chanes, J., 2016. Minimally processed foods. *Encycl. Food Health* 767–771.
- Baschali, A., Tsakalidou, E., Kyriacou, A., Karavasiloglou, N., Matalas, A.-L., 2017. Traditional low-alcoholic and non-alcoholic fermented beverages consumed in European countries: a neglected food group. *Nutr. Res. Rev.* 30 (1), 1–24.
- Becoming a vegetarian, 2020. Harvard health. Retrieved March 28, 2022, from <https://www.health.harvard.edu/staying-healthy/becoming-a-vegetarian>.
- Chandra, S.P., Vianney, Y.M., Christie, T.L., Wongso, M., Widjaja, M., Yang, D.C., Kang, S.C., Atoum, M.F.M., Sukweenadhi, J., 2021. Mass production of *Panax ginseng* CA Mey. Root cultures in Indonesia. *Sarhad J. Agric.* 37 (1), 98–109.
- Chang, H.-O., Wang, S.-W., Chen, J.-C., Hsu, L.-F., Hwang, S.-M., 2001. Mutagenic analysis of fermenting strains and fermented brine for stinky tofu. *J. Food Drug Anal.* 9, 45–49.
- Chen, H., McGowan, E.M., Ren, N., Lal, S., Nassif, N., Shad-Kaneez, F., Qu, X., Lin, Y., 2018. Nattokinase: a promising alternative in prevention and treatment of cardiovascular diseases. *Biomark. Insights* 13, 1177271918785130.
- Cornet, S.H.V., Snel, S.J.E., Schreuders, F.K.G., van der Sman, R.G.M., Beyrer, M., van der Goot, A.J., 2021. Thermo-mechanical processing of plant proteins using shear cell and high-moisture extrusion cooking. *Crit. Rev. Food Sci. Nutr.* 1–18.
- Coskun, F., 2017. A traditional Turkish fermented non-alcoholic beverage, “shalgam”. *Beverages* 3 (4), 49.
- Dávila-Aviña, J.E., Ríos-López, A., Aguayo-Acosta, A., Solís-Soto, L.Y., 2020. Probiotics in fresh-cut produce. In: *Fresh-cut Fruits and Vegetables*.
- Di Cagno, R., Filannino, P., Gobbetti, M., 2016. Fermented Foods: Fermented Vegetables and other products. *Encycl. Food Health* 668–674.
- Dinu, M., Abbate, R., Gensini, G.F., Casini, A., Sofi, F., 2017. Vegetarian, vegan diets and multiple health outcomes: a systematic review with meta-analysis of observational studies. *Crit. Rev. Food Sci. Nutr.* 57 (17), 3640–3649.
- Do Espírito Santo, A.P., Perego, P., Converti, A., Oliveira, M.N., 2011. Influence of food matrices on probiotic viability – a review focusing on the fruity bases. *Trends Food Sci. Technol.* 22 (7), 377–385.
- Gao, S., Sun, Z., Du, X., Mao, C., He, G., 2021. Effect of inoculating lactic acid bacteria starter in low-salt pickle process of Zhacai. *Adv. J. Food Sci. Technol.* 4 (6), 442–444.

- Garbett, T.M., Garbett, D.L., Wendorf, A., 2016. Vegetarian diet: a prescription for high blood pressure? A systematic review of the literature. *J. Nurse Pract.* 12 (7).
- Hargreaves, S.M., Raposo, A., Saraiva, A., Zandonadi, R.P., 2021. Vegetarian diet: an overview through the perspective of quality of life domains. *Int. J. Environ. Res. Publ. Health* 18 (8), 4067.
- Hemler, E.C., Hu, F.B., 2019. Plant-based diets for cardiovascular disease prevention: all plant foods are not created equal. *Curr. Atherosclerosis Rep.* 21 (5), 18.
- Jou, H.-J., Tsai, P.-J., Tu, J.-H., Wu, W.-H., 2013. Stinky tofu as a rich source of bioavailable S-sequol in Asian diets. *J. Funct. Foods* 5 (2), 651–659.
- Kim, J.Y., Gum, S.N., Paik, J.K., Lim, H.L., Kim, K.C., Ogasawara, K., Inoue, K., Park, S., Jang, Y., Lee, J.H., 2008. Effects of nattokinase on blood pressure: a randomized, controlled trial. *Hypertens. Res.* 31 (8).
- Kinney, M.J., Weston, Z., Bauman, J.D., 2019. Plant-based meat manufacturing by extrusion. In: *Overview of Plant-based Meat Manufacturing*. The Good Food Institute.
- Link, R., 2018. Natto: the fermented soy superfood with benefits. Dr. Axe. Retrieved October 19, 2021, from <https://draxe.com/nutrition/natto/>.
- Marcus, J.B., 2013. Chapter 10-Weight management: finding the healthy balance: practical applications for nutrition, food science and culinary professionals. In: *Culinary Nutrition: the Science and Practice of Healthy Cooking*, pp. 431–473. Elsevier Science.
- Marriott, B.M., 2000. Functional foods: an ecologic perspective. *Am. J. Clin. Nutr.* 71 (6), 1728S.
- Medawar, E., Huhn, S., Villringer, A., Witte, A.V., 2019. The effects of plant-based diets on the body and the brain: a systematic review. *Transl. Psychiatry* 9 (1), 226.
- Mitrofanova, T., 2020. History's craziest diet fads. Tape worm pills, arsenic poisoning cigarette diet, and vinegar water? I guess I'll stick with keto diet. Published in *Lessons from History*. <https://medium.com/lessons-from-history/histories-craziest-diet-fad-s-f1330a282b47>. (Accessed 11 May 2022).
- O'Donnell, C.D., 2020. Alternative proteins: the problems and the promise. *Food Process.* Retrieved May 21, 2021, from <https://www.foodprocessing.com/articles/2020/alternative-proteins-the-problems-and-the-promise/>.
- Oei, V., 2020. Plant-Based meat alternatives set to thrive in the next five years. *Nutr. Biosci.* Retrieved May 25, 2021, from <https://www.dupontnutritionandbiosciences.com/news/nutrition-biosciences/2020/plant-based-meat-alternatives-set-to-thrive-in-the-next-five-years.html>.
- Park, K.Y., Jeong, J.K., Lee, Y.E., Daily, J.W., 2014. Health benefits of kimchi (Korean fermented vegetables) as a probiotic food. *J. Med. Food* 17 (1), 6–20.
- Patra, J.K., Das, G., Paramithiotis, S., Shin, H.S., 2016. Kimchi and other widely consumed traditional fermented foods of Korea: a review. *Front. Microbiol.* 7, 1493.
- Pot, G., Prynne, C., Almoosawi, S., Kuh, D., Stephen, A.M., 2015. Trends in food consumption over 30 years: evidence from a British birth cohort. *Eur. J. Clin. Nutr.* 69, 817–823.
- Putri, K.A.E., Sriati, Yunita, 2018. The consumer perceptions and organizational strategy of Indonesia vegetarian society (IVS) in increasing to consumption vegetable cuisine in Palembang city. *IOSR J. Bus. Manag. (IOSR-JBM)* 20 (8).
- Qian, F., Liu, G., Hu, F.B., Bhupathiraju, S.N., Sun, Q., 2019. Association between plant-based dietary patterns and risk of type 2 diabetes: a systematic review and meta-analysis. *JAMA Intern. Med.* 179 (10), 1335–1344.
- Raak, C., Ostermann, T., Boehm, K., Molsberger, F., 2014. Regular consumption of sauerkraut and its effect on human health: a bibliometric analysis. *Glob. Adv. Health Med.* 3 (6), 12–18.
- Rakuten Insight, 2022. Report: Plant-Based Food Alternatives. <https://insight.rakuten.com/report-plant-based-food-alternatives/>. (Accessed 25 March 2022).
- Ramachandran, D., Kite, J., Vassallo, A.J., Chau, J.Y., Partridge, S., Freeman, B., Gill, T., 2018. Food trends and popular nutrition advice online – implications for public health. *J. Publ. Health Inf.* 10 (2), e2013.
- Rani, V., Arora, A., Ruba, P.H., Jain, A., 2018. Composition of functional food in world diet. *Funct. Food Hum. Health* 3–14.
- Shahbazi, R., Sharifzad, F., Bagheri, R., Alsadi, N., Yasavoli-Sharahi, H., Matar, C., 2021. Anti-inflammatory and immunomodulatory properties of fermented plant foods. *Nutrients* 13 (5), 1516.
- Sucheta, Singla, G., Chaturvedi, K., Sandhu, P.P., 2020. Status and recent trends in fresh-cut fruits and vegetables. In: Siddiqui, M.W. (Ed.), *Fresh-Cut Fruits and Vegetables: Technologies and Mechanisms for Safety Control*. Academic Press, pp. 17–49.
- Sumi, H., Hamada, H., Tsushima, H., Mihara, H., Muraki, H., 1987. A novel fibrinolytic enzyme (nattokinase) in the vegetable cheese Natto; a typical and popular soybean food in the Japanese diet. *Experientia* 43 (10), 1110–1111.
- Summerfield, L.M., 2012. A plant-based diet is not necessarily a vegetarian diet. Many people on plant-based diets continue to use meat products and/or fish but in smaller quantities, second ed. In: *Nutrition, Exercise, and Behavior: An Integrated Approach to Weight Management*. Cengage Learning, pp. 181–182.
- The Jakarta Post, 2018. Vegan Festivals to Promote Local Dishes to Foreign Visitors. <https://www.thejakartapost.com/news/2018/03/07/vegan-festivals-to-promote-local-dishes-to-foreign-visitors.html>. (Accessed 22 July 2022).
- The World's Most Vegetarian Countries, 2017. Oliver's Travels. Retrieved May 20, 2021, from <https://www.oliverstravels.com/blog/most-vegetarian-friendly-countries/>.
- Top 10 Companies In Plant Based Food Market, 2021. Meticulous Market Research. Retrieved May 21, 2021, from <https://meticulousblog.org/top-10-companies-in-plant-based-food-market/>.
- Tur, J.A., Bibiloni, M.M., 2016. Functional foods. In: *Encyclopedia of Foods and Health*, pp. 157–161.
- van der Laarse, M.C., 2015. Vegetarianism and veganism in Indonesia. <https://studentthe.se.universiteitleiden.nl/handle/1887/42157>.
- Vegconomist, 2022. Meatless Kingdom: Mushroom-Based Meat Alternatives from Indonesia - Vegconomist - the Vegan Business Magazine. <https://vegconomist.com/company-news/meatless-kingdom/>. (Accessed 25 March 2022).
- Wan, L., 2018. Asia Dominates Vegetarian Markets But Understanding Local Factors Crucial For Sales Success. *Food Navigator Asia*. Retrieved March 25, 2022, from <https://www.foodnavigator-asia.com/Article/2018/07/02/Asia-dominates-vegetarian-markets-but-understanding-local-factors-crucial-for-sales-success>.