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PLANT-BASED MEAT: A SUSTAINABLE ALTERNATIVE TO MEAT

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ABSTRACT
Due to the increase in the world population, the amount of meat used in human consumption has also increased in recent years. On the other hand, it is clear that animal-based meat production cannot sustain this growth and results in more pollution, land and water use, greenhouse gas emissions and biodiversity loss than the pollution occurring in plant food production. For this reason, there has recently been a trend towards new protein sources that meet the protein requirements of the human diet and improve animal welfare without increasing the carbon footprint. To respond to this increase and to to mitigate the adverse effects associated with animal production, plant-based meat production (PBM) has recently received attention. Here we have tried to provide detailed information about the production methods, product features and consumer preferences of PBM alternatives.
Keywords: Plant based meat, product features, consumer preferences, production methods

BİTKİ BAZLI ET: ETE SÜRDÜRÜLEBİLİR BİR ALTERNATİF

ÖZ
Son yıllarda artan dünya nüfusuna bağlı olarak insan beslenmesinde kullanılan et miktarı da artış göstermektedir. Buna karşın hayvansal et üretiminin bu artışı karşılayamayacağı ve bitkisel gıda üretiminde meydana gelen kirlilikten daha fazla kirliliğe, arazi kullanımına, su kullanımına, sera gazı oluşumuna ve biyolojik çeşitlilik kaybına yol açmakta olduğu gerçeği ortadadır. Bu sebeplerle insan beslenmesinde protein ihtiyacını karşılayacak ve karbon ayak izinin artışına yol açmayacak ayrıca hayvan refahını iyileştirecek yeni protein kaynaklarına yönelim son zamanlarda artış göstermiştir. Bu artışı karşılayabilmek ve hayvansal üretimde meydana gelen olumsuzlukları bertaraf etmek için bitki bazlı et (BBE) üretimi son zamanlarda ilgi uyandırmaktadır. Tüketicinin et yerine bitki bazlı yapay et (BBE)'i tercih etme ya da etmemesinin sebeplerinin ve tercih ettiğinde kendisine nasıl fayda sağlayacağının bilinmesi gerekmektedir. Burada bitki bazlı et alternatiflerinin üretim yöntemleri ürün özellikleri ve tüketici tercihleri ile ilgili detaylı bilgiler vermeye çalıştık.
Anahtar kelimeler: Bitki bazlı et, ürün özellikleri, tüketici tercihleri, üretim yöntemleri

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INTRODUCTION

It is estimated that food production accounts for 20-25% of human greenhouse gas emissions, with most of the carbon footprint coming from animal production (Bhattacharyya et al., 2023; Ahmad et al., 2022). It is reported that the world population will reach 9 to 10 billion people by 2050, the global demand for meat will reach 455 million tons, and the demand for food will increase by 98% (Rubio et al., 2020; Bhattacharyya et al., 2023). In this sense, the biggest challenge for global food security is meeting the demand for protein in a healthy and environmentally friendly way. In livestock production, it is reported that 81,7% of protein is lost during the conversion of feed and grass protein into meat protein (Zhang et al., 2022). Moreover, without alterations to current food production and supply systems, the rapid increase in global demand for animal protein is anticipated to be inconsistently fulfilled (Huang et al., 2022). In particular, livestock farming causes more pollution, land and water use, greenhouse gas emissions, and biodiversity loss than plant-based food production (McClements & Grossmann, 2021). Furthermore, producing one unit of plant-based protein requires only one-twentieth of the land resources needed to produce an equivalent unit of conventional meat protein (Papies et al., 2020). For these reasons, there has recently been a trend towards new protein sources that meet the protein needs of human nutrition and improve animal welfare without increasing the carbon footprint. Reflecting this trend, plant-based meat alternatives and cell-based meat have recently been launched to meet consumer demands and shape the future of foods (Kumar et al., 2022; Wang et al., 2023).

Extensive land usage is often leading to deforestation through the process of clearing land for grazing purposes. Livestock production systems also disrupt nitrogen and phosphorus cycles, affecting air, water and soil quality. This means that a transition to sustainable production and a shift of consumers to sustainable foods can prevent future environmental crises. Although animal-based meat is a valuable source of nutrients, reducing meat consumption is necessary because of the negative impacts of meat consumption on the environment and human health (Bhattacharyya et al., 2023). Today, as the world's population grows, our food choices influence not only our health and well-being, but also climate change and the future of our planet. Global food and agricultural productions account for a third of all greenhouse gas emissions, and animal-based meat production causes twice as much pollution as plant-based food production (Bhattacharyya et al., 2023). Compared to traditional animal-based proteins, the production of alternative plant-based proteins results in significantly fewer greenhouse gas emissions (e.g. 1/8 CO_2 equivalent per kilogram for chicken, 1/12 for beef and 1/9 for pork). (Ye and Mattila 2022). Excessive meat consumption has also been associated with several health problems. Red meat contains high amounts of cholesterol and long-chain saturated fatty acids, so excessive consumption of red meat may increase the risk of chronic diseases (Godfray et al., 2018). More than 1.8 million people die from ischemic heart disease every year, and a quarter of them are linked to excessive consumption of certain meat products (Rubio et al., 2020). In addition, consuming fatty meat increases the risk of cardiovascular disease and cancer, and consuming wild meat increases the risk of transmission of the virus from wild animals to humans. The results of a clinical trial reported that participants who used plant-based meat instead of animal-based meat for eight weeks exhibited a lower risk of cardiovascular disease (for example, reduction in fasting serum trimethylamine-N-oxide levels) (Crimarco et al., 2020).

It is believed that the health and environmental impacts of animal meat production and consumption can be eliminated by consuming sustainable foods such as plant-based meat alternatives to animal protein sources.

PLANT BASED MEAT PRODUCTION

Plant-based meats (PBM) are made from plant-based ingredients (such as beans, legumes, lentils and grains) and provide a sustainable source of protein that is similar to animal meat in texture, flavor, color and nutrition profile (Santo ve ark.,

2020). Innovations in protein ingredients evolve with diverse portfolios through the use of new proteins such as fava bean protein and mung bean protein, as well as microalgae, seaweed and fungi, and sweet lupine (chosen for its lack of alkaloids) (Boukid 2021). Besides all these plant protein sources, insects and single-cell proteins have recently gained interest as alternative protein sources due to their high nutritional value and protein content, sustainability and affordability (Boukid 2021). Commonly used plant protein sources are cereal (rice, wheat, oat, barley, core), legumes (soy, peas, lentils, beans, edamame), oil seeds (sunflower, sesame, canola, coconut), green leaf (beet, alfalfa, algae, duckweed), nuts (peanut, almond, pistachio, macadamia), pseudo cereal (chia, foxtail, quinoa), and others (mushroom, potato) (Wang et al., 2023).

In a study measuring the effectiveness of consumer reactions to plant-based burgers, 368 consumers rated images of the same plant-based burger online, along with information about the type of plant protein (soy, pea, or wheat). Plant-based protein type (soy, pea and seitan (wheat)) had no effect on consumer response, but meat reduction attitudes had a significant and strong impact (Moussaoui et al., 2023).

Table 1 lists the most commonly used protein sources for plant-based meat production, their functional properties and their uses in plant-based meat production.

Table 1. Summary of already used protein ingredients for meat analogue applications (Kyriakopoulou et al., 2021).

Protein Ingredient	Composition (%*w*/*w*)	Functionality	Application in Meat Analogues
Soy isolate (alkaline/acid precipitation treatment)	~90 % protein	Gelling, Good solubility and emulsification	Structuring process: Extrusion, spinning, freeze structuring, shear cell Role: Protein source, binder, texture, base for fat substitutes, emulsifier Products: Burger patties, sausages, minced meat
Soy isolate (additional heat treatment/ toasted isolate)	~90 % protein, denatured due to heat treatment	Decreased solubility, good gelling and increased water holding capacity	Structuring process: Shear cell, Extrusion, Role: Texture, Protein source, binder, base for fat substitutes Products: Burger patties, minced, sausages, meat
Soy concentrate	~70 % protein	Good texturization properties	Process: Shear cell, Extrusion, Role: Protein source, binder, texture Products: Burger patties, sausages, muscle-type products, minced meat
Soy milk spray dried powder	>45% protein, ~30 % fat	Good emulsification properties, high solubility	Process: Freeze structuring Role: Texture, emulsifier Products: Production of yuba and tofu
Soy flour/meal defatted	~43–56% protein, ~0.5-9% fat, ~3–7% crude fibre, >30% total carbohydrate	Native protein, Water binding capacity and fat retention	Process: Extrusion Role: Binder, Texture Products: Burger patties, sausages, muscle-type products, minced meat
Wheat Gluten isolate	75–80% protein, 15–17% carbohydrates, 5–8% fat	Dough forming/ Cross-linking capacity via S-S bridges, binding, low solubility	Structuring process: Shear cell, Extrusion Role: Texture, Adhesion Products: Muscle type products, Burger patties,
Pea isolate	~85% protein	Water and fat binding, emulsification, and firm texture after thermal processing	Process: Spinning, extrusion, shear cell Role: Binder, emulsifier, texture Products: Burger patties, sausages, minced meat, muscle-type products

Yang et al. (2023) presented the contents of four different plant-based meat analogs purchased from the market in America and China (Table 2). In their study, the protein level of meat was higher than 25 g/100 g, and the protein content of selected plant-based meat analogs was between 14.1-19.8 g/100 g. The average sodium content of the meat analogs used in the study was roughly 7.9 times higher than that of meat. Compared with red meat, plant-based meat analogs presented lower protein digestibility and released less bioactive peptides after in vitro digestion. In this instance, the consumption of plant-based meats presents certain drawbacks when compared to the consumption of animal meat in the human diet. PBMs accessible in the market mimic meat in three forms: grounds (such as patties, burgers, and nuggets), emulsions (sausages), and loose "crumbles" (chili meats or taco) (Pingali et al., 2023).

Table 2. The ingredient of the four plant-based meat analog products (Yang et al., 2023).

Product	Country	Ingredient
P1	America	Water, Methyl cellulose, Rapeseed oil, Refined coconut oil, Natural flavors, Rice protein, Cocoa butter, Potato starch, Phospholipid, Pea protein, Concentrated apple, lemon and pomegranate juice, Concentrated beet juice, Minerals and salt etc.
P2	America	Water, Soy leghemoglobin, Sunflower oil, Coconut oil, Zinc gluconate, Natural flavors, Potato protein, Cultured glucose, Yeast extract, Modified starch, Salt, Soy protein, Thickener (E461), Antioxidant (E306), Isolated soy protein, Niacin, Vitamin B1, B2, B6, B12, etc.
P3	China	Water, Soy protein, Guar gum, Cheese, Protein powder, Starch acetate, Protein solution, Sunflower oil, Spices, Acid hydrolyzed vegetable protein, Methyl cellulose, Edible glucose, Coconut oil, Salt, Yeast extract, Arabic gum, Beet juice extract, 5'-disodium nucleotide.
P4	China	Water, Isolated soy protein, Beet powder, Vital wheat gluten, Methyl cellulose, Vegetable oil, Edible glucose, Yeast extract, Pea protein, Lohan-kuo extract, Arabic gum, Starch acetate, Spices, Salt, etc.

Plant and fungi-based meat products incorporate the flavor, texture, and/or nutritional properties of meat, but have different compositions. Plant-based meat products can be divided into two flexible categories based on development time and technological complexity: traditional meat analogues and new plant-based meats. Traditional meat analogs have existed for thousands of years in Asia and include relatively simple derivatives of soy (such as tofu and tempeh) or wheat (seitan). On the other hand, new PBMs are characterized by the design and marketing of products that are almost equivalent to animal meat in all aspects, including taste, texture and nutritional value (Rubio et al., 2020).

Typically, PBM production involves three stages.
-Protein Isolation: Target plant proteins are extracted from plants, some of which undergo hydrolysis to improve their functionality such as solubility and cross-linking capacity.
-Formulation: The texture of the meat is improved by mixing ingredients such as plant proteins, food adhesives, plant-based oil and flour. Nutrients are added to match or exceed the nutritional profile of the meat.
-Processing: Plant proteins and other ingredients are mixed to create a meat-like structure through a protein reshaping processes (including stretching, kneading, cutting, pressing, folding and extruding) (Rubio et al., 2020).

A sustainable substitute to intensive animal-based meat production ought to be the development of plant-based meat alternatives with a fibrous and meat-like texture, that could be produced by means of extrusion technology, shear cell technology, self-assembly, spinning (electrospinning and wet-spinning), freeze casting, and by culturing mycoproteins (Zhang et al., 2022).

Extrusion is one of the cheap and short-term methods often used in the production of meat analogues to imitate the structural and textural properties of meat. The extrusion process can be divided into two groups based on moisture content: low moisture extrusion (20-35%) and high moisture extrusion (50-70%). High moisture extrusion of plant proteins is suitable for the production of meat analogues due to the targeted fiber structure that the cooling zone of this extrusion can provide. The use of high temperature and pressure causes changes in protein structure, gelatinization of starch, and destruction of anti-nutrient compounds in the process (Aydar et al., 2023).

The machines currently used for the production of PBMs are mainly divided into single-screw extruders and twin-screw extruders, depending on the number of screws (Wang et al., 2023). For high moisture extrusion, an interlocking and co-rotating twin-screw extruder is used, which mainly consists of the screw in the extruder barrel and the cooling die installed at the end. Approximately five steps are required for protein texturing from raw materials to the final extruded product, including raw material supply, mixing with water, melting, mold forming (die) and cooling (Zhang et al., 2022).

Innovative technologies are used to improve the organoleptic properties of PBMs include mycelium cultivation, 3D printing, shear cell technology and recombinant proteins (Rubio et al., 2020).

Traditionally, plant-based meat alternatives have been developed based on recipes that have been around for decades. The quality characteristics of meat substitutes, such as consistency, taste and color, depend on the choice of ingredients. The average consumer's choice of alternative meats is heavily influenced by excellent taste and flavor. Flavors, spices and precursors are used together with iron complexes to mimic the taste of meat (Ahmad et al., 2022). The meat alternative formula contains approximately 50-80% water, 4-20% non-textured protein, 10-25% plant protein, 3-10% flavor enhancing additives, 0-15% fat, 0-5% coloring agents (beet juice, carrot juice extract, lactoferrin and red yeast rice) and 1-15% binding substances. When combined, these ingredients provide meat alternatives with the essential sensory and textural properties. The high water content not only reduces costs, but also provides the required hydration, works as a softener during the process and aids emulsification. Protein added for nutrition provides texture, taste and physical appearance. Textured proteins can be replaced by mixing proteins from non-meat sources with meat or by replacing meat entirely with textured proteins to produce vegan and vegetarian foods. Meat extenders do not have the appearance, texture or taste of meat when cooked, but when mixed with meat they improve the overall quality characteristics of the product. Meat alternatives, on the other hand, are designed to mimic the texture, appearence, taste and color of meat when cooked without meat-containing ingredients (Sha and Xiong, 2020). Studies have shown that the addition of red beet, monascus red, oleoresin paprika, sorghum, and cacao to PBM as a single pigment does not adequately mimic the target color values for the exterior and interior of cooked meat. It has been shown that the cooked color of PBM can be achieved by using an optimized mixing ratio of red beet and cacao pigments (0.4 to 1.5 mg/g red beet and 1.1 to 1.3 mg/g cacao pigments). Furthermore, sensory evaluation showed that the color of PBM with optimum pigments was most similar to a beef patty, increasing the general acceptability of the improved appearance properties (Bakhsh et al., 2022; Ryu et al., 2023).

PBMs are frequently labeled using vegan and/or meat-like names (for example vegan meatloaf or soy burger). There is no clear definition of what

the term "vegan" means and no regulation explaining whether PBM can be labeled using meat-like names (Domke, 2018). Lima et al., (2023) found that the labels of 59 plant-based products sold in ten supermarkets in Brazil frequently included the phrase 100% vegetable.

Whole-muscle meat, on the other hand, has a fine texture that is microscopically similar to myofilaments in terms of tenderness as well as juiciness, making it difficult, if not impossible, to make from plant proteins. As a result, product development research on plant-based substitutes has been generally limited to restructured or reconstructed products. These meat-free products can be divided into two main groups: coarse-grained products and fine-grained products. Coarse-grained products include meatless burgers, patties, sausages and chicken nuggets. Fine-grained products are frequently emulsified products such as sausages and alternative salami. (Sha & Xiong, 2020).

Plant-based meat analogs contain proteins, fats or oils, carbohydrate sources, flavourings, coloring and binding agents. All these factors can contribute to meat analogues that resemble animal meat in terms of nutritional, textural and organoleptic properties. For instance, protein sources such as soy, gluten and pea proteins have nutritional and texturizing properties. They are also used for their other functional properties such as water and oil binding, emulsification, foam stabilization and gel formation during processing. Fats increase the juiciness, tenderness, nutritional value and overall taste of emulsion-type meat analogues. They are also significant components as key determinants of storage stability (Chen et al., 2023).

Animal meat products are commonly accepted by consumers due to the chewy taste provided by their fibrous structure. Although commercially available plant-based protein meats can largely mimic the fibrous taste of different animal meat products, there are still some problems with the overall texture and quality. Although some reconstituted ground meat products have been produced commercially in imitation of animal meat, whole meat (e.g. steak) has a complex hierarchical structure of muscle tissue, adipose tissue and connective tissue surrounding the muscle fibers. The complexity of muscle fibers makes it very difficult to fully understand their physical, chemical and functional properties. How to convert plant globular proteins into meat-like fibers to meet tissue necessities is a vital area of future research (Liu et al., 2023).

Most meat substitutes are derived from soy protein because it has particularly desirable properties and are available at low prices. In addition to soy protein, other proteins from oilseeds and proteins obtained by fermentation by microorganisms on various substrates are used in the production of meat substitutes. Currently, meat substitutes are produced using proteins derived from cereals such as corn, rice, wheat, defatted oilseeds, bean flour and cereals, defatted derivatives of soy flour and wheat flour, soy protein concentrates and wheat flour. Fermentation technology is also used to create meat color (Ou et al., 2023).

When the raw materials are heated, chemical changes occur that change the spices and flavors added to the premix. In addition, depending on the nature of these compounds, complex chemical reactions can occur at high pressure and temperature, releasing volatile components and causing significant loss of taste. In addition, heat treatment such as extrusion causes flavor components such as salt, acid compounds and sugar to interact with the protein network, leading to changes in taste quality and, as a result, changes in structural and textural characteristics. It can also affect Maillard or other chemical reactions (Ahmad et al., 2022). For this reason, it is very important to optimize the flavor and taste quality of plant-based meat and to control the quality of raw materials and the appearance of flavor.

The main organoleptic (i.e. sensory) characteristics of meat are appearance, aroma, taste and texture. Depending on the product, PBMs aim to mimic the appearance of raw or precooked meat. Heat-stable fruit and vegetable extracts (e.g. apple pulp, beet juice) or

recombinant heme proteins (e.g. LegH) are used to both regenerate the color of fresh meat and turn it brown when cooked. Some newer PBM products display visible semisolid plant-based oils (e.g., coconut oil, cocoa butter) to mimic the appearance of oil. Engineering is essential to comprehensively express the taste, smell, flavor and aroma of meat. Meat analogues contain flavor additives to add, enhance or mask specific flavors and typically represent 3 to 10% of the product. Many plant proteins have a bitter and astringent taste and require post-processing to selectively remove these compounds. Soy products in particular have a strong grassy, beany and bitter flavor related to saponin, lipoxygenase, and isoflavone compounds, which can be reduced by heating or germination. Developed in the 1980s, synthetic meat flavors consist of sugars, amino acids, nucleotides, glycoproteins, monosodium glutamate, salt and fat and have been shown to be equal to or better than meat extracts via sensory panels. Recombinant protein additives such as LegH can affect both the taste and color of PBMs. PBM texture may be affected by high moisture extrusion mycelium cultivation, shear cell technology, and 3D printing. Shear cell technology, extrusion and 3D printing are based on applying thermal, mechanical, and shear stresses to protein mixtures to obtain semi solid fibrous structures. Although many strategies are existing to design and tune the structure of plant proteins, it can be challenging to balance processing techniques to achieve the preferred mechanical properties while maintaining nutritional value. In contrast, mycelium cultivation includes the growing filamentous fungi, some strains of which resemble the microstructure of meat. Quorn™, a fungal based meat analogue, has provided alternative to meatballs, chicken nuggets, and minced meat since the 1960s. New startups grow mycelium to produce high quality meats such as steaks (Rubio et al., 2020).

THE PLACE OF PLANT BASED MEAT IN NUTRITION

The main plant proteins used in PBM formulations (pea, soy, and wheat) provide the same level of total protein content as animal meat. However, complementing more than one plant-based protein is often necessary to provide a balanced amino acid profile. For example, legume proteins (low in sulfur containing amino acids and high in lysine) and grain proteins (low in lysine and high in sulfur containing amino acids) proteins are suitable complements. Factors that reduce nutrient bioavailability of plant proteins after ingestion include protein structure, proteolysis-resistant structures, and antinutrients (such as tannins, phytates, and lectins). Some processing techniques such as soaking, heating, sprouting have been shown to increase digestibility (Rubio et al., 2020).

Nutrition also varies between traditional and new PBM products. For instance, tofu (traditional PBM) and Impossible™ (new PBM) share several benefits over animal meats, such as containing dietary fiber and mineral contents and lack of cholesterol. However, tofu-specific benefits include fewer calories, less fat, and no sodium. Impossible™-specific benefits include higher protein and vitamin B12 content. Concerns about the inclusion of LegH in PBM have been expressed with reference to correlations between heme iron intake and increased risk of diabetes (Rubio et al., 2020). Yeo et al., (2023) reported that, compared to meat products commonly consumed in Singapore, plant-based meat analogues contained significantly higher calcium, manganese, iron, magnesium, sodium and copper than meat products. They also reported that meat products had significantly higher mean potassium concentration compared to PBM.

Besides appearance, texture and flavor, nutritional value is also a crucial factor in why consumers select plant-based meat analogs. In a study on the nutritional composition of meat products and traditional meat products, Bohrer (2019) found that meat-like products were lower in saturated fatty acids and cholesterol and higher in carbohydrates and dietary fiber than traditional meat products. Zhou et al. (2021) investigated the in vitro digestion properties of beef and beef analogs. The results showed that the beef analog protein was digested faster in the stomach, but the protein and fat digestibility of the beef analog was

lower. In a study by Xie et al. (2022), plant-based analogues of beef and pork were found to have lower digestibility and release fewer potentially bioactive peptides than beef and pork.

CONSUMER OPINIONS ABOUT PLANT BASED MEAT

Plant-based products contain a wider range of phytochemicals and nutrients than animal meat. PBM meat reduces greenhouse gas emissions by 78-96%, resulting in a lower carbon footprint than conventional meat. Additionally, PBM production is more sustainable because it causes less damage to biodiversity. Plant-based meat alternatives, as sustainable products, have received increasing attention in recent years due to their potential to decrease the environmental impacts during production and consumption. Yet, it is hard to convince consumers of sustainable consumption through PBM. Consumers believe that PBMs are better for the environment and their health, but only a minority choose to buy PBMs. Moreover, meat consumption can only be reduced if meat consumers are convinced that sustainable food consumption brings environmental and personal benefits. Therefore, understanding consumers' perceptions of PBM is crucial from both environmental and marketing perspectives (Bhattacharyya et al., 2023). In a study conducted in South Africa, Szejda et al. (2021) reported that knowing about PBM has a significant positive relationship with PBM purchase intention. A recent study using Nielsen Consumer Panel data (Cuffey et al., 2021) shows that the majority of consumers did not consume PBMs until 2019. It also found that PBM spending among consumers dropped 75% after the first purchase, indicating that most consumers are buying PBM to try it out rather than consuming it on a regular basis.

Based on home scanner data for nearly 39 000 households in the United States from 2018 to 2020, 80% of households never purchased PBM and instead purchased only ground beef. Additionally, 17% of households purchased both ground beef and PBM. Of the remaining households that bought PBMs during the survey period, 40% were novelty seeking and one time purchasers (Neuhofer ve Lusk, 2022). Zhao et al. (2022) analyzed market spending data from 2017 to 2020 to evaluate consumers' PBM demand in the United States. According to data, US consumer purchasing patterns indicate that PBM is a complementary product to beef and pork and a substitute for chicken, turkey and fish.

Motivators behind consumer purchase/ consumption of plant-based meat substitutes may relate to traditional factors (taste, cost and convenience) and/or emerging factors (health and fitness, environment, safety, animal welfare and familiarity). Demotivators behind consumer purchase/consumption of plant-based meat substitutes may relate to health, environmental awareness, familiarity, meat attachment, meat enjoyment, men food, and food nephobia (Boukid 2021).

To be successful, plant-based meat alternatives must taste like meat. Taste (including mouthfeel) is very important in motivating regular meat consumers to change their eating habits by reducing meat consumption (Tuorila & Hartmann, 2020). Ideally, it is significant to mimic the properties of meat products before, during and after cooking. For instance, a beef steak analogue ought to be shiny, pinkish-reddish and tough before cooking, while becoming dull, brownish, tender and juicy after cooking, and this transition should take place under the same time temperature conditions as seen in a real beef steak (McClements and Grossmann, 2021). According to an online survey study with participants from Germany (N= 1039), meat substitutes have the best chance of effectively replacing meat when they thoroughly resemble highly-processed meat products in texture and taste and are offered at a competitive price. It is therefore recommended that alternative meat producers focus on imitating processed meat products rather than imitating cuts of meat such as steak or escalope (Michel et al., 2020).

Despite increasing consumer awareness of environmental issues, the consumption of plant-based protein foods instead of meat appears to face several obstacles in Western countries.

Consumers are reluctant to make this dietary change because of the traditional pleasure of eating meat, its nutritional and sensory appeal, and the convenience it provides (Kyriakopoulou et al., 2021). Even though many companies and researchers have produced plant-based meat analogs, there are still alterations in color, texture, smell, taste, flavor, mouthfeel, and nutritional properties compared to animal-based meat (Wen et al., 2023). Schouteten et al. (2016), in a sensory panel study comparing animal, plant and insect-based burgers, stated that animal burgers were associated with the emotional terms `satisfied, happy and pleasant', whereas plant burgers were associated with 'disappointed, insecure and displeased'. However, beef-like products are produced today, and extensive research is needed on consumer acceptance of these products. Neff et al. (2018) reported that interest in purchasing plant-based meat varies by age, gender, income, education and region.

Bryant et al. (2019) in a cross-country (US, China, and India) study found that the attitudinal determinants of purchasing similar meat in the US were attractiveness, excitement, and low disgust, whereas in China, health, appeal, taste, and sustainability were the primary determinants; and in India, sustainability, excitement, necessity, and goodness were predictors of intention to purchase plant-based meat. In a hypothetical choice experiment, Slade (2018) offered consumers the option of purchasing burgers made from beef, plant-based protein, or cultured meat. Willingness to purchase plant-based and cultured meat burgers was reported to be linked to age, gender, views on other food technologies, and attitudes toward the environment and agriculture. Although consumers in this study were told that all burgers tasted the same, their preference for beef burgers was clear. A mixed logit model predicts that if prices were the same, 65% of consumers would not buy a beef burger, 21% would buy a plant based burger, 11% would buy a cultured meat burger, and 4% wouldn't buy one.

The best-selling category of plant-based meat alternatives is burgers and patties ($120 million). Are plant-based meat products really good for the world? How serious is the situation in real meat production? How does it taste and look, does it have the texture of meat and the experience of cooking or eating real meat? What ingredients does it consist of? Are allergen warnings correctly stated on the label? In what quantities are the various additives used to create meat-like texture, juiciness and taste? Make sure that plant based meat is not a laboratory mixture of chemicals and that its ingredients contain the same amount of protein as real meat burgers. Is the source of plant protein used correctly stated? It is emphasized that these questions of consumers regarding nutrition, food safety, clean labeling, and cost and consumer self-confidence need to be answered. (Ahmad et al., 2022).

Estell et al., (2021) a plant based diet was explained as ‘following a vegan diet’ (55.3%, n = 352), 38% (n = 244) of participants expressed a plant based diet as ‘following a flexitarian diet’ and 27.8% (n = 177) explained it as ‘a vegetarian diet’. In open-ended responses, the most common sources of plant protein were tempeh, legumes, tofu, nuts, soy, whole grains, vegetables, and meat substitutes.

Van Loo et al. (2020) in their results from random parameter logit models indicate that, constant prices and conditional on choosing only a food product, 72% preferred farm raised beef and 28% preferred one of the alternatives, 16% plant based (pea protein) meat substitute, 7% plant based (animal like protein) meat substitute and 5% lab grown meat. With the addition of brand names (Certified Angus Beef, Impossible Foods, Beyond Meat and Memphis Meats), the percentage of farm-raised beef selection has increased to 80%. Environmental and technical information had little influence on the market conditional potrtion, but reduced the proportion of individuals who did not buy the option, showing that the information appeals more individuals to the market. Even though plant-based and lab-grown alternatives have seen noteworthy price discounts (50%), farm-raised beef sustains the largest market portion. Vegetarians, men, and the young and well-educated individuals are relatively more likely to prefer plant-based and lab-grown alternatives

to farm-raised beef. Judge and Wilson (2019) reported that female consumers prefer plant-based foods more than male consumers.

Studying 526 consumers in Beijing, China, Wang et al., (2022) investigated how food characteristics and information influence consumers' food choices regarding plant-based meat products. A discrete choice experiment was conducted using burgers with five characteristics (meat patty, sodium content, energy, flavor and price) as primes. To help examine the role of information, consumers were randomly presented with individual messages about food safety, nutrition, and environmental issues related to eating plant-based meat. This study shows that consumers in Beijing have relatively low knowledge of plant-based meat and have a negative preference for eating plant-based meat compared to conventional meat. Nevertheless, although consumers' willingness to pay for plant-based meat increased significantly after receiving nutritional information, they did not respond to the provision of food safety or environmental information. These findings propose that to support plant-based meat consumption, at least in the context of Beijing, China, information should be presented that is closely related to consumers' personal interests rather than the "public interest."

Seo et al. (2023) conducted a study using behavioral evidence theory to understand how PBM alternatives and characteristics influence consumer decision-making processes in a foodservice context. The results of the study showed that reasons "for" and "against" the use of PBM were significantly related to attitudes. Additionally, when the responsibility attributed to environmental problems was evaluated to investigate whether it could lead to more positive attitudes towards PBMs, it was reported that as the attributed responsibility increases, the health benefits operate more strongly, and low product availability and its negative impact on attitudes decrease as the attributed responsibility increases. Cor van der et al., (2019) reported that, in addition to different levels of technological innovation, a variety of social and institutional changes are needed for meat alternatives to achieve greater success. In Western societies, meat is deeply institutionalized. Eggs, dairy products, and cultured meat also fit into current dietary patterns. Significant changes in insect and algae consumption are required, and while legumes and plant-based alternatives are now institutionalized options, niche products have existed or remain, although there are signs of increasing social value (Cor van der et al., 2019).

CONCLUSION

Plant-based meat has taken a significant place as a choice rather than meat not only for vegetarians and vegans, but also for all consumers, as consumers' awareness of the negative effects of meat consumption on health and the environment has increased in recent years. Yet, to sustain this increase in consumption, the basic taste and texture that determine consumer preference must be improved. Developing ingredients that provide the desired meat-like texture and flavor as well as selecting/optimizing processing may be suitable increase strategies. In PBM production, it is required to use additional ingredients other than protein to mimic other sensory properties of meat such as color, aroma and mouthfeel. The diversity in ingredients and functionality requirements across different types of plant-based meat analogues (sausage and burger) complicates product development. It should also be emphasized that high-tech and potentially disruptive new options in PBM require a high degree of social coordination to make them feasible. Considering that recent studies have focused on the analysis of nutritional composition differences between plant-based and animal-based meat, a detailed comparison of their nutritional and digestive properties would be more useful for optimizing plant-based meat formulations and developing healthy products. Additionally, future events and policies are needed to clarify regulatory uncertainties surrounding plant-based analogues. Food labeling, health and nutrition claims ensure that consumers' trust in this product is placed on a solid and transparent basis.

CONFLICT OF INTEREST

The author inform no conflict of interest.

ETHICAL STATEMENT

The authors state that no ethical approval was needed.

AUTHOR CONTRIBUTION

All authors contributed to the manuscript writing and approval of the final version.

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