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Plant-based meat alternatives: Compositional analysis, current development and challenges

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ABSTRACT

Plant-dependant meat replacements are produced to meet consumer demands and to produce viable food supplies in the future. They have almost similar nutritional profiles as animal sourced meats. Meat alternatives helps to mitigate the negative impacts of livestock on the environment and human health. Recent product development efforts and marketing have increased plant-based meat alternatives production. However, it is still at its initial stage and faces numerous technological challenges. Processing technology innovation and creative product formulations are currently focused on improving meat-like quality characteristics. The inclusions of a variety of additives to produce meat-like texture, juiciness, mouthfeel, and flavour, raise concerns about nutrition, food safety, clean label, cost, and consumer confidence. This review assessed materials and processes associated with meat analogues, current development, challenges at the market and amongst consumers and opportunities for future growth.

1. Introduction

Plant-dependant meat analogues are a good source of protein and their consistency, colour, nutrition and taste can match specific meats (Choudhury et al., 2020). Traditionally, plant-dependant meat replacements are developed on decades-old recipes (Joshi & Kumar, 2015). Mushrooms, rice, lentils, soy protein, and wheat gluten were all treated with meat like flavour additives making a finished product that feels like meat (Joshi & Kumar, 2015). Tempeh and Tofu products derived from soybeans are very well known plant-dependant meat replacements. Various kinds of plant proteins, including wheat gluten, are also utilised in conventional foods such as seitan (Kyriakopoulou et al., Dekkers et al., and Goot et al, 2019). Plant-dependant meat substitutes involve analogues based on textured vegetable protein (TVP), it is a dry immense product that is derived from soy concentrates (Malav et al., 2015).

Analogue is a substance that is similar in structure with each other but slightly different in makeup. Meat analogue or mimic meat in this scenario is a foodstuff that seems to be similar in structure to meat but differ significantly in composition. Meat like compound or substance made from plant sources is simply called meat analogue. Plant-based meat, vegetarian meat, meat substitute, mimic meat, meat replacement, synthetic meat, or amalgam meat are some of the most commonly used names. Mock meat almost has the same aesthetic attributes (like consistency, taste, physical appearance) or chemical-based traits of special meat kinds.

Due to the worldwide demand for sustainable meals as a consequence of the involvement of animal foods as well as other environmental effects, industries have expanded their focus on developing meat replacements. The faux meat market is dependant on “meat reducers,” a group of consumers interested in mostly weight and health maintenance. There are numerous health-related benefits of eating meat analogues as reduced consumption of meat may help in decreasing cholesterol levels and thereby prevents heart-related issues, daily consumption of original meat is also associated with colorectal cancers (Hu et al., 2019). Plant-based meat is currently gaining huge interest amongst researchers due to high consumer demand because of health problems associated with daily consumption of meat or due to obligations of consuming a vegetarian diet in particular religious’ sections. The literature about meat-based alternatives is summarised to provide a handful of information to researchers for restructuring plant meat. This review discusses the

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materials & processes that are used for structuring meat analogues. The consumer behaviour of plant-based meats and their industrial opportunities for sustainable food supply was also analysed. This article will be helpful to assess the materials, processes and products in future studies related to meat analogues.

2. Materials used for plant-based meat alternatives

The quality attributes of meat alternatives like consistency, taste, colour, etc. are based on the selection of ingredients. Meat alternatives have almost 50 - 80% water content, non-textured based protein 4–20%, vegetable textured based proteins 10 - 25%, additives for flavour enhancement 3–10%, fats 0–15%, colouring agents 0–5% and binding agents 1–15%. When these components or ingredients combine they provide meat alternatives with required sensorial and textural characteristics. The high water content not only reduces costs but also produces the required juiciness, it works as a softener during the process and aids in emulsification. The protein added for nutrition provides texture, taste, and physical appearance. The textured proteins can be replaced either by mixing the proteins from non-meat source with the meat or by completely replacing the meat with the texturizing proteins to produce full vegetarian and vegan food. When cooked, meat extenders do not have the texture, appearance or taste of meat, but when blended with meat, they enhance the overall quality attributes of the product. Meat alternatives, on the other side, are designed to mimic the form, texture, taste and colour of whole meat when moistened and cooked without components that contain meat (Sha & Xiong, 2020). As a result, minimal chemicals or additives could be utilised to enhance the raw materials' final consistency. To improve the holding capacity of water, concentrates of soy protein, egg white, gluten from wheat, or other adhesive agents like starches and hydrocolloids are used. The consistency, taste, or form of the product are deciding traits in the satisfaction of consumers.

2.1. Proteins

The demand for proteins from plant sources is increasing and it is influenced by a variety of parameters, including cost, accessibility, compatibility for incorporation into new products, and, most significantly, their physiological properties (Haque et al., 2016). Functions of protein include water and oil retaining capabilities, dissolving, emulsifying, gelation and foaming properties, which are important for the creation of the meat-substitutes structure. These functional properties are dependant on the kind of protein (amino acid sequencing, chemical structure, higher or secondary level structure). The factors of the environment like temperature, pH and ionic strength, etc. can change the structure of protein and functionality of proteins. The focus of the research is to develop an understanding related to the process structure-function association of food proteins. their importance and how the quality and the functional properties of proteins help to build the meat-like structure and consistency (Singhal et al., 2016). Most of the meat replacements are derived from soy protein because it has desired specific traits and is available at a low cost. Along with soybean protein, the protein from other oil-seeds plants and proteins produced by fermentation on various substrates by microorganisms, have been utilised for the production of meat alternatives (Kim et al., 2011). Currently, the meat alternatives are also manufactured by utilising proteins from cereals like maize, rice, wheat, de-fatted oil seed, bean flours and cereal, derivatives and meals from defatted soy flour, soy protein concentrates, wheat flour (Kumar et al., 2017). Edible fungi and micro-algae are recently used as textured protein sources in a meat-alternative formulation (Zhang et al., 2022).

2.1.1. Soy protein

Soy proteins are added in the meat-replacements recipe as flour, soy isolates or soy protein concentrate. Soy proteins have been widely used in meat alternatives because of their desired functional properties, such as water-holding, gelling, fat-absorbing, and emulsifying capacities. In soybean products, the flour of soy is the least processed. Different kinds of flours are present in the market like toasted flour, full fat and defatted flours, etc. Defatted flour can be synthesized by mashing the flakes of soy that is defatted and it contains the protein about 50%. Soybean isolates and concentrates which contain a higher amount of protein than soy flour are produced by simply fractionating the flakes of defatted-soy. The concentrates are extracted in liquid alcohol and result in a product that contains 70% content of protein, on the other hand, isolates are extracted in alkaline solution, followed by precipitation process at low acidic pH and yields in 90% protein content. Besides being high in protein, soy protein isolate has a bland flavour and a light colour in comparison to other proteins. which is a desirable attribute for the formation of meat analogues. However, for meat replacement application, purity of protein does not need to present on a high level (Geerts et al., 2018; Goot et al., 2016). Although, the existence of additional components can be essential and even beneficial while making the alternatives of meat (Grabowska et al., 2016)

2.1.2. Gluten from wheat

The gluten from wheat contains the inherent capacity to form elongated narrow protein layers, that can be easily changed to fibrous structure. The importance of protein desulfation bonding in the formation of a three-dimensional structure is a critical characteristic of gluten (Ooms et al., 2018), which provides a fundamental component for fibrous structural developments (Krintiras et al., 2015; Nawrocka et al., 2017; Pietsch et al., 2017). The hydrogen bonds, disulphide bonds and hydrophobic interactions in wheat gluten are found to be responsible for the formation of meat-like structures and also their retention and stabilisation during product formulation (Chiang et al., 2021). The wheat gluten was found to produce desirable dough for the development of meat analogues (Chiang et al., 2021).

2.1.3. Protein from legumes

Proteins legumes from lentils, chickpea, lupine, peas, and different kinds of beans are studied for gel creation, stabilisation of foam and emulsifying properties (Berghout et al., 2015; Ladjal-Ettoumi et al., 2016). Amongst these, pea protein, which was structured via high-moisture extruded, is by far the most viable for meat-substitute applications. Pea components are softer than soy products, the strength is however improved by modifying the protein-hydrogen interaction, for instance, by the addition of salts with ions of chaotropic (Osen and Schweiggert-Weisz, 2016) and by adjusting process conditions like protein molecule size, temperature, and so on. Different studies on lentils, lupine, and chickpea have proved that they have good stabilisation of foam and emulsion properties. However, several studies suggest that pre-treatments of legumes can influence gelatinisation activity. Legume proteins particularly from pea have shown to form fibrous meat structures (Plattner, 2020). The protein isolates with high protein content increase hardness and chewiness in meat analogues, with an increase in protein content the structural strength was found to be increased due to protein-protein cross-linking network, however, the curring strength (textural properties) of meat analogues is also dependant on the temperature of extruder (Sha & Xiong, 2020). The oat fibre and pea protein isolate were combined at varying ratios and processed by extrusion under high moisture to develop the fibrous meat analogues (Kaleda et al., 2021). The meat chunks produced were long and thin-looking fibres, which was also examined under electron micrograph as shown in Fig. 1.

2.1.4. Proteins from oil seeds

Canola and rapeseed are two other noteworthy proteins source with good emulsifying and foam formation properties (Chang et al., 2015; Ntone et al., 2022). When utilised at great pressure or heat, rapeseed proteins can begin gelatinisation, which could lead to forming just meat-mimic consistency. Furthermore, napin has yet been proposed

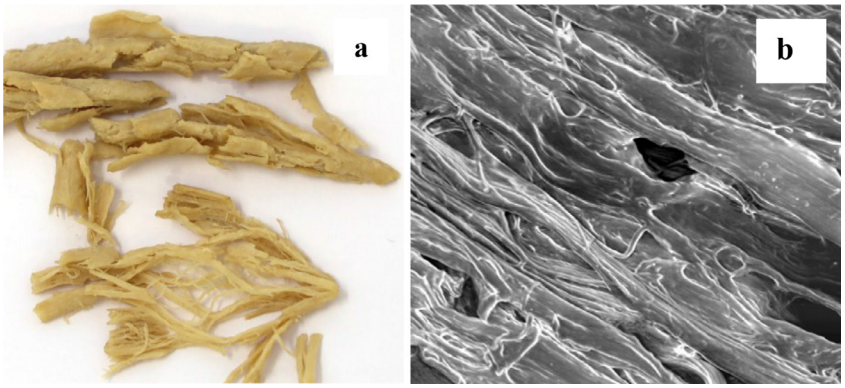

Fig. 1. (a) Intact and pulled Structure of oat-pea meat analogues after rehydration (b) Fibres and pores as observed under scanning electron microscope adapted from Kaleda et al. (2021).

as a casein-containing compound extender, because it creates aggregation with β-casein in solution provoked by salt-bridging, ionic, and hydrophobic bindings (Schwartz et al., 2015). Fractions of protein of canola, mainly depend on globulins or albumin and could create the coherent gel-like form under the concentration of salts. Very powerful and flexible connections were found when canola protein was combined with k-carrageenan, showing that canola protein can act as a reagent for building structure.

2.2. Oil and fats

The meat replacements that are present till now have less concentration of fats as defatted materials are most commonly used to make meat replacements. Furthermore, oil or fat addition during processing influences the fibrous structure formation. In previous investigations, it was reported that in the processing of extrusion, recipes that have oil greater than 15% causes lubrication of materials, which can negatively impact the macromolecule alignment. The material could become slick, which has an adverse influence on the shearing forces at work in the extrusion process. However, adding vegetable oil and fat to a meat-replacement dish has benefits, as it can enhance tastiness, softness, and flavour, these are very important features for the buyer that could be present in a slice of meat. As a response, protein components, such as moderately fermented soy proteins that include fat in their natural form, are added into meat substitutes (Geerts et al., 2018). These components could be used as a replacement or supplement to the fat added to the products by combining them into the finished product formula. Canola oil, Rapeseed oil, Soya oil, Palm oil, Coconut oil and Sunflower oil are some of the fats and oils that nowadays used for plant-based meat replacements. Adding oil or fat seems to be vital because it can increase the taste of the meat-alternatives.

2.3. Binding agents

Binder in meat substitutes can be compounds derived from plants or animals that act as both moisture and fats binders. Such components comprise wheat gluten, xanthan gum, isolate of soy protein and eggs, and carrageenan others. Many components may serve as adhesives and enhancers depending on the quantity used. Ingredients high in proteins have water-binding and protein network formation as the main function, whereas components with low or no protein levels, such as starches and flour, play the role of fillers although their fat and water holding capacities through entrapment. The impact of binding agents at various concentrations on quality attributes and nutritive values of plant-based substitutes is still being studied. There are reports available on the formulation and the use of binding materials in texturizing products date back to the early 1980s. Binding protein for texturizing proteins depends on milk and water with 10 and 20%, gluten 1–5% and albumin 10–20%. The quality of the final product is highly dependant on the type and concentration of binding agents (Arora et al., 2017). The effects of casein, concentrate of soy protein, and xanthan gum was tested on mushroom-based sausage equivalents produced with 5% fats (Arora et al., 2017). Wheat gluten is a potential binding agent because of its adherent and elastic character (Nawrocka et al., 2017). Another element which is utilised in meat substitutes is egg albumen, which causes adhesion and provides desirable physiochemical properties, besides increasing the protein content. The concentrates of soy, flour of soy and isolates of soy have also been used amongst them soy isolates are preferred and most commonly used. Different polysaccharides like guar, cellulose, and pectin are admirably used in meat-substitute extender and binder (Varadan et al., 2015)

2.4. Taste and flavouring enhancers

The average consumer's preference for meat alternatives is heavily influenced by excellent flavour and taste. To mimic the flavour of the meat, savoury aromas, spicing and precursors are being used with the complexes of irons (for example chlorophyllin of ferrous or protein that contains haem) (Fraser et al., 2017). The raw materials undergo chemical changes while heating and alter the spices and aromas that are added in the premix. Furthermore, based on the nature of these compounds, complicated chemical reactions can take place under high pressure and temperature, volatile constituents are released that results in considerable flavor loss. Furthermore, thermal treatment like extrusion, causes alterations in the flavour quality, due to interactions of component of taste like salt, acidic compound and sugar with the protein network and causing a change in structural and textural properties. It may also affect maillard or other chemical reactions (Guo et al., 2020) like new flavour chemicals may be developed from amino acids and sugars (Sun et al., 2022). Amongst aromas produced, the roasted aroma is the most desired, though a danger for off-flavor formation remains. Therefore, optimising the taste and flavour qualities is a complex process, whereby quality of raw materials and monitoring of aroma manufacturing are crucial (Lu et al., 2018). Furthermore, volatile aroma components produced when meat is cooked have been investigated. Several compounds including such sugar (reducing) (Xylose, glucose, ribose, and fructose), amino acids (cysteine, cystine, proline, lysine, serine, methionine, threonine), nucleotide, and thiamine are also used to duplicate the aromas in meat substitutes (Fraser et al., 2017). Wu et al. (2000) reported that aroma like chicken and beef can be made from the soybean-dependant enzyme-hydrolysed protein that is vegetable-based by altering the pH reactions, during roasting, egg-like, bean-like, apple sauce-like and molasses-like aromas are perceived at decreased intensity under optimum circumstances It was noticed that hydrolysis of vegetable protein/D-xylose/L-cysteine system attributes some sulfur-bearing substances and provides a characteristic meat like flavour. The ribose/cysteine reaction was influenced by heterocyclic substances that contain sulfur, which is the main developer to the overall meat like the product's structure and texture formation. Therefore, the optimisation

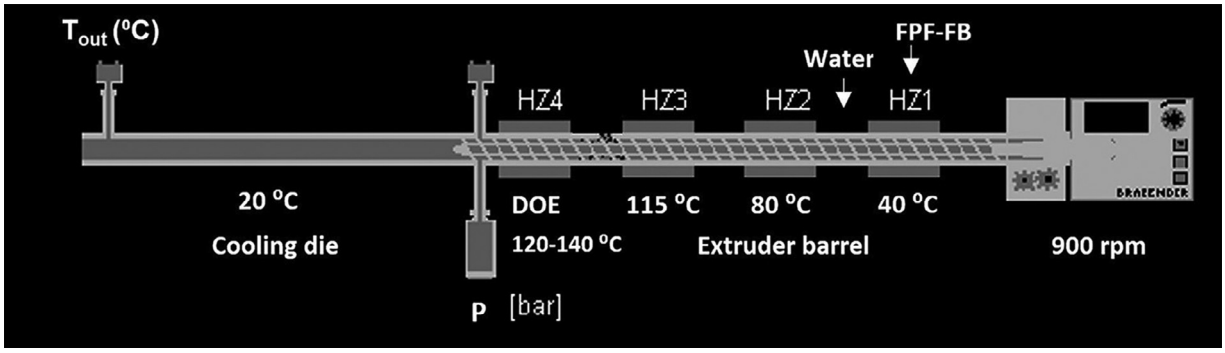

Fig. 2. Extruder set up for the meat analogue products adapted from Saldanha do Carmo et al. (2021) HZ1: Heating zone 1; HZ2: Heating zone 2; HZ3: Heating zone 3; HZ4: Heating zone 4.

of the flavour and taste perception quality is a challenge, for which the quality of the raw materials and the monitoring of aroma formation are important (Lu et al., 2018).

2.5. Colouring agents

Colour is considered as the most important quality characteristics in meat. A meat alternative should have the same colour as that of original meat, that's why colouring additives are indeed an essential addition. The colouring agents are particularly added because the protein used for example soy protein and gluten, give a taint or yellow-brown hue to the flesh which is quite different from the brown colour of cooked beef or reddish-pink colour of flesh. Nowadays, thermostable colouring compounds such as caramel colours, annatto or malt, cumin, turmin, and carotene are employed (Malav et al., 2015; Rolan et al., 2008; Vrljic et al., 2015). As in meat preparation, the conversion of nitrosylmyoglobin coverts into the substance known as nitrosylhemocrome leads in a color change typically appears red to pink. A similar change in colour may occur when cooking meat substitutes. Depending on the final product's qualities, heat-labile colourants and reducing chemicals are added to make the product look like both raw and cooked meat (Rolan et al., 2008). The colours that are unsteady in heat are degraded or demolished at a great temp. Beetroot extracts and betadine are the suggested colour extracts to mimic meat. Moreover, sugar (reducing) can be used as an agent for browning, the amine of protein group in a reaction that is similar to maillard type reaction, parallel to browning of the meat. It is likely to add dextrose and other reducing sugars such as mannose and arabinose as well as maltose and lactose (Rolan et al., 2008) to the mix. Before structuring treatment, colourants are pooled with plant-based proteins and smeared as colouring solutions. The other method consists of mixing colourants with the protein-containing material after the structuring process i.e. after injecting into the extruder barrel. The colour of meat alternative is a challenging task as, despite the availability of different colourant and embodiment methodologies, the colour of meat analogues is not as similar to original meat. This may be because the optimal pH range of the colourant is different as present in meat alternatives. This can be however by adjusting the pH using acidulants, such as citric acid, acetic acid, lactic acid or their combination. The colour migration from meat alternatives is another hurdle that can be controlled by using colour retention aids such as maltodextrin and hydrated alginate (Orcutt et al., 2008).

3. Formation of meat analogues using high moisture extrusion

The meat analogues are structured mostly by high moisture extrusion processing; the plant proteins are fed to extruders along with ingredients to form meat-like fibrous structures. Extrusion with less than 40% feed moisture is termed as low moisture extrusion and extrusion with more than 40% feed moisture is high-moisture extrusion. The high moisture extruder set up for the development of meat analogues is shown in Fig. 2. High moisture extrusion is considered suitable for obtaining fibrous products that give original meat like mouthfeel and texture. The proteins are denatured and unfold by high moisture heat treatment, then there is a realignment of protein strands due to shearing forces, moisture, heat, pressure and cooling process. During realignment, there is crosslinking due to disulphide bond formation, which is an important interaction for the formation of fibrous structures. Therefore, proteins with high cysteine content are preferred in meat analogues (Pöri et al., 2022; Zahari et al., 2020). The process parameters of extrusion is an important factor that determines the bite-feeling, elasticity/firmness, and sensory attributes of the product. Different ingredients and proteins sources need adjustment in the temperatures, feeding rate and moisture ratio to develop desirable fibrous and textural attributes. Meat analogues were produced from faba beans between the temperature ranging from 130 to 140 °C, with water and product feed rate of 4 and 11 rpm (1.10 Kg/h) produces good sensory and textural properties in the final product (Saldanha do Carmo et al., 2021). Oat fibre and pea protein isolated were combined to process under High moisture extrusion with long cooling and temperatures at 40, 60 and 80 °C to obtain fibrous meat analogues, the long cooling was found to strengthen the structure (Ramos Ramos Diaz et al., 2022). Soy-beans are most commonly used for the development of meat analogues through high moisture- extrusion process (Heusala et al., 2020). Therefore, the properties of structured meat depend on the processing conditions as well as on the composition of raw material (Kyriakopoulou et al., 2019).

4. Consumer preference for plant- based meat alternatives

It's not just our health and well-being that's affected by what we eat, but also the future of our planet. There is an undoubted indication that the extreme consumption of meat is Sans & Combris (2015) negatively influencing the environment in a substantial manner (Aiking & de Boer, 2018). About 30% of global warming and climate change originate from the food industry in the present day. There's distinct apprehension about animal-based protein because great volumes of the protein cause water depletion as well as climate change and phosphorus cycle disruption. Environmental and health trials must be addressed by decreasing meat intake and increasing the use or intake of plant-based foods (de Boer & Aiking, 2019; Graça et al., 2019; Godfray et al., 2018; Springmann et al., 2018; Van der Weele et al., 2019; Willett et al., 2019; Aiking & de Boer, 2018; Poore & Nemecek, 2018). Human health and animal prosperity are openly affected by the destructive effects of livestock farming (Raphaely & Marinova, 2016). The scenario for world population growth is expected that by 2050 there will be 8 billion people on this planet (United Nations, Department of Economic and Social Affairs, Population Division), and the demand for meat and dairy merchandises will remain

to climb, making severe difficulties. Consumers may switch to a more plant-based diet and diminish the intake of meat (Onwezen & Van der Weele, 2016). Vegetable proteins can be replaced for meat to make a diet further environmental friendly. The end-user has the choice of replacing meat with a meat alternative or adding substitute protein sources such as beans and seafood in their cuisine. Dairy and meat ingestion must be reduced in Western European countries. One way to accomplish this is to exchange meat with meat substitutes. Food replicators that hire egg white, grains, or fungus as a protein source have appeared on the market in recent years, and cultured meat is reaching its market introduction. A superior understanding of the potential boundaries, loads, and aptitudes related to meat alternatives as a protein source is essential. It's no secret that vegetarian and vegan ways of life have amplified the popularity of meat alternatives, but in most Euro nations, they are still infrequent (Siegrist & Hartmann, 2019). Buyers are not worried about the outcome of meat intake, according to studies (Hartmann & Siegrist, 2017), As a result, the bulk of meat production practices are unethical (Hartmann & Siegrist, 2020). There's a solid connection between eating meat and having good health. Mammal muscle meat was favourably correlated with maleness in one study and females are more accepting of vegetarian and vegan diets than males (Judge & Wilson, 2019). Only a small percentage of consumers habitually buy meat substitutes (Hagmann et al., 2019; Siegrist & Hartmann, 2019), Consumers hardly purchase meat substitutes, according to a recent survey (Lemken et al., 2019). Vegetarians and vegans are more likely than meat-eaters to approve that vegetarian and vegan diets are healthier for animal health and the environment (Bryant, 2019). Most consistent meat substitute buyers have had positive reactions to healthier meat alternatives. When it came to steady consumers, meat alternatives were more popular than meat, but non-consumers of meat alternatives favoured meat over meat alternatives. Meat substitutes that are analogous to meat are desired by consumers who want analogues meat. Various aspects affect people's consumption of meat alternatives. Consumption is more likely to shift to plant-based alternatives amongst consumers that value the environment. Women also seem to prefer meat substitutes. Well-educated people are more likely to ingest meat substitutes. There are several impediments to the consumption of meat substitutes, including unfamiliarity and lack of sensory appeal, taste, affordability, and convenience are all aspects that dissuade individuals from eating a vegan diet (Bryant, 2019). Both non-users of meat substitutes and meat substitute users approve that the ideal meat substitute should be cheaper than meat and contain more protein, vitamins, and fewer calories than meat. Other dynamics, such as the setting in which meat alternatives are consumed, could affect their compatibility. To some extent, how people respond to meat alternatives, as well as whether or not they flourish, is determined by the societal standards that govern what is appropriate in specific situations (Higgs, 2015), How others eat has an impact on what's considered acceptable in any specific scenario, when a vegetarian diet is regarded as being more comparable to a vegan one, it is more positive. People are more likely to alter their eating customs to match those of their peers, according to the outcomes of another study (Higgs & Thomas, 2016). A vegetarian host may be regarded as more trend-conscious, health-conscious, and apprehensive about animal wellbeing than a meat-serving host and may thus act as a role model for their companions (Funk et al., 2020). When determining whether or not meat substitutes are fitting, it is vital to consider the context in which you will consume them. One of the objectives of the study was to measure consumers' associations with meat and meat substitutes. In the process, we were able to acquire a better knowledge of how meat and meat substitutes are perceived by individuals. To better recognize what inspires people to eat meat, as well as what discourages them from doing so, we may use this information. A plant-based meat substitute may be accepted differently depending on the intake context, according to our hypotheses we believed that meat substitutes would be more broadly accepted when it came to eating non-traditional meals for instance alone eating in-home) comparison with the formal situation of eating for example business meal). Customer perceptions of particular meat classes and meat substitutes, as well as future expectations for new substitutes, were all studied as part of this research. Such information is essential for the growth and marketing of meat substitutes.

5. Industrialisation of plant-dependant meat substitute

There was $939 million worth of US plant-based meat substitutes sold in the US in 2019, accounting for 2% of all retail packaged meat sales and roughly 1% of all retail meat purchases in the US (adding powdered milk replacements to the list and other dairy products) in 2019. Plant based meat alternatives is predicted to reach ~US$27.9 billion by 2025l The Union Bank of Switzerland (UBS) projects plant-based-protein or alternative-meat market to reach US$85 billion by 2030 at an impressive estimated compound annual growth rate (CAGR) of 27.5%). A GFI report indicates that the top-selling categories in plant based meat alternatives were burgers (US$283 million), links (sausages and hot dogs; US$159 million),and patties(US$120 million) in 2019. In terms of the geographical spread of plant-based meat alternatives companies, the majority (61) are based in North America and 17 are in Europe, whereas only a handful are in Asia, Australia, or Africa

6. Plant-dependant meat substitute as a pathway to a sustainable food supply

Vegan meat substitutes have a prodigious deal of promise in terms of resource proficiency and market appeal. Nevertheless, there is still a way away to make it prosperous. The accessibility of plant-based meat analogues to customers has only been extended up to 1% from 2013. (U. S. Plant-dependant overview of the market). Plant-dependant meat substitutes can keep moving frontward notwithstanding animal agriculture's declining returns in quality and efficiency after millennia of optimisation. Plant-based meat replacements will become even more enjoyable, economical and environmentally based sustainable as a result of the outcomes of public research that has already been conducted. Our labeling necessities must be established on common sense and evidence-based safety norms to accomplish this goal. It is likely to hurry the transition to a sustainable food system if food firms, food service providers, governments and environmental advocates offer institutional assistance

7. Plant-based meat alternative products and consumer's perceptions

Impossible Food Inc. also known as "Impossible" is company, based in Redwood City, California, makes plant-based meat products with tastes and texture similar to that of original meat. They are specialised in several products such as burgers, Meatballs, Pizza, Tacos, and Bao and many other foods. Their meat products are not only distinguished by their taste and texture, but they also propose an equal nutritional profile as that of real meat to the people to eradicate the supposed negative health impacts of real meat and the certain environmental impacts associated with livestock products. Impossible uses modern science and technology to make a healthy and nutritious food system. The company's signature product, the Impossible Burger, was launched in 2016. This burger has no hormones, antibiotics, and has a delightful pork flavour, It is added with vitamins from granules, vegetables and seeds, fats and a few acids to revive sustainably viable meat. Presently, their products are accessible in a few states in countries like Hong Kong, Singapore and the United States of America,

Individuals are anxious with How does it taste? And how does it look, feel and if it has the experience as that of cooking or eating real meat? What all constituents is it made up of? And that it is not just a lab chemical concoction and if these ingredients contain the same amount of proteins as that of real meat burgers. Whether plant based meat products are really beneficial for the planet? And how severe is the situation with production of real meat. People who intake real meat can be categorised into two sections:

(1) People who like eating meat but even after looking at the effects of animal farming are stuck with eating real meat as there is no better alternative present.
(2) People who are not really worried about the environmental effects caused by animal farming and like to eat meat due to its taste and texture and experience.

Impossible Foods Inc. is on a mission of provide products for not only the people present in the first category that are concerned with harmful environmental effects due to animal farming but also for the people present in the second category by making their plant-based meat products taste and feel exactly the same as that of real meat and provide a more healthy category for everyone as well as for the planet. Hence the concerns regarding tastes were answered by Impossible with their Impossible Burger and other plant-based meat products. But to accomplish such a huge feat, Impossible Foods choose the perfect constituents for making a burger (plant based meat patties) taste the same as real meat patties (Soham Gade, 2020).

Impossible uses only six ingredients such as:

- Soy Protein
- Potato Protein
- haem (short for Hemoglobin): A secret ingredient of Impossible
- Cellulose based culinary binder: To hold everything together
- Coconut and Sunflower Oils
- Water

8. Challenges and opportunities in plant-based meat alternatives

Latest exertions in creative development and marketing have managed a spike in the creation of plant-based meat substitutes. There are technological and consumer disputes that must be spoken about before this initial momentum can be maintained. At least initially, simulating an animal's sensory potentials (texture and flavour) has proven challenging when it comes to producing muscle-like tissue. Customer acceptability of such items is determined by aspects such as look, taste, texture and mouthfeel according to innumerable consumer surveys, e.g., by Weinrich (2019). A mix of technical innovation and new product formulations will remain to advance meat quality features shortly. A diversity of additives used to attain meat-like texture, juiciness, and flavour advances questions regarding nutrition, food safety, clean labelling, cost and consumer self-reliance.

8.1. Properties related to sensory attributes

Due to the natural variances amidst muscle and plant materials, such as protein molecule structure, amino acid composition, peptide sequences, and chemical composition, animal meat products are problematic to reproduce. Plant-based alternatives must have a meat-like texture and water-binding ability. Thermal mechanical extrusion and shearing are instances of positive structural approaches (Dekkers et al., 2018). Although plant proteins are critically denatured, their aggregates do not microscopically match a muscle fibre or a fibre bundle's anisotropy in three dimensions. According to the study, the most anticipated structural properties of beef are the muscle fibre structure and its capacity to immobilise water. A diversity of thickening, water binding, and texture-enhancing chemicals are used in alternative possessions made from plants to reimburse for these variances It is still a typical criticism that the cooked food is parched (low in moisture). Additional hurdles comprise substitute meat alternatives' inability to replicate the familiar and estimated taste of animal flesh (Graça et al., 2019). There is a range of spices and herbs, as well as those used in meat processing, that are added to simulate processed meat flavours. The taste of many plant-based substitutes is not spiteful. This odour is hypothesised to be instigated by the compounds hexanal and methanethiol. Its bitter-astringent flavour may be due to the existence of soy proteins' naturally occurring saponin and isoflavones. To imbue fresh hamburgers with the colour of blood, haemoglobin from the legs has been added. Combine with nitrite to give cooked beef reddish colour (nitrosyl hemochrome) and nitro-like flavour. Naturally, the economic viability of viable alternatives must be evaluated. To minimise the influence of these undesirable flavours, soy protein isolate or concentrate should be made. Vegan products are hindered by the inability to consume red meat (fresh) or pink (nitrite cured). Infusing fresh hamburgers with haemoglobin from the legs has resulted in a reddish hue. Combine with nitrite to give cooked beef reddish colour (nitrosyl hemochrome) and nitro-like flavour. Economic viability, of course, is a significant consideration. According to reports, plant-based meat substitutes are healthier and more nutritious than traditional animal meat. Nevertheless, the fact that most non-meat items are heavily processed is not always indicative of good intentions. Plant-based alternatives may inevitably miss some of their nutrients due to rigorous processing (blending, homogenisation, high-temperature cooking). Plant-based alternatives have a limited number of nutritional studies to display their precise health benefits compared to meat's nutrient makeup (Ayivi et al., 2021). As an example, the biological efficacy of inorganic minerals added to a product's recipe is not well-established. To reduce salt levels and promote health benefits, meat analogues often contain more sodium than the original meat items they are intended to replace. Soy-based formulation components should be checked for anti-nutritional factor inhibitors. Phytase, for instance, can reduce soybean protein isolates from 8.4 mg per gram of protein to less than 0.01 mg per gram of protein by using the enzyme (Hurrell et al., 1992). Soy protein isolates also have trypsin inhibitors (Kunitz and Bowmaan-Birk inhibitors) at concentrations ranging from 1 to 30 (Isolate) milligrams per gram. It's a recognised fact that protease inhibitors are heat-sensitive (Arntfield, 2018) their destruction at moderate heating requires longer for example heating at 93 °C requires 1 h for their deactivation. One of the possible means to lower the content of the enzyme inhibitors in legume protein ingredients (isolates or concentrates) for meat alternatives is ultra-high temperature pretreatment. According to Kwok et al. (1993), more than 75% of the trypsin inhibitory activity in soymilk was lost after 45 s of heat treatment at 121 °C. The another challenge for Plant-based meat alternatives is that they encompass a large number of constituents, usually above 20 (and as many as 40), which makes difficult to provide a clean label of ingredients on the final product. For instance, titanium dioxide, methylcellulose and lecithin are additives not found in regular meat products commercial replacement products (such as burgers and nuggets) contains about 20–30 additives (Bohrer, 2019). The additives may include preservatives, stabilizers, and colorants that are not commonly added in regular meat products, for example, titanium dioxide, methylcellulose, and lecithin. Due to addition of large number of ingredients, there is no-clarity and doubts have raised, whether meat alternatives are truly healthier and more nutritious than meat. Further, toxicants and poisons such as heterocyclic aromatic amines can also be produced during the high-temperature processing of protein-rich foods (Barzegar et al., 2019). However, such type of toxicants has also been reported for meat subjected to high-temperature cooking, including grilling, roasting, frying, and baking (Jiang & Xiong, 2016). When cooked at high temperatures (grilling or frying), plant-based meat substitutes are vulnerable to harmful chemicals because of their high protein content. However, more detailed research in needed to validate the previous findings. Addition of natural phenolic compounds could be good strategy to improve the safety and reduce the toxicants in the processed meat alternatives. The another hurdle for meat based alternatives is due to presence of some allergic plant proteins, such as soybean protein (G2 Glycinin, which binds to IgE) that can provide health hazard to consumers. From light to severe, the degree of sensitivity can be wide-ranging. The Food and Drug Administration (FDA) has revoked its 1999 health claim that soy protein is helpful to human cardiovascular health . Gluten sensitivity, intolerance, and allergy are potential threat aspects for coeliac disease that must be closely monitored in vulnerable groups (Miller, 2018). Besides this, meat analogues have high-moisture

content, therefore proper storage, packaging and microbiological safety should be investigated.

9. Future research and conclusion

Vegetarians and meat-eaters alike can benefit from protein-rich legumes and cereals. Until the market for meat substitutes matures, food scientists and entrepreneurs will have numerous possibilities to test fresh conceptions. It has been a key focus of product growth and applied research for many years to advance meat substitutes that feature texture-related sensory qualities Plant proteins can be altered into fibres or non-filamentous protein aggregates using old and emerging technologies. Plant proteins have not yet been able to produce myofibrils, muscle cells, and muscle tissue, as well as their water-binding (juiciness) and mouthfeel qualities. Therefore, it is compulsory to carry out more thorough investigations that are top-down. An ingredient functionality study is also essential to explore the meat-like flavour and aesthetic features of the ingredients. Spices and flavour extracts can easily be used to generate meat-like flavours and conceal unwanted off-flavours. If we improve both the efficacy of proteins (better function) and the overall quality of developed products, we can increase market volume due to increased consumer acceptance. In deduction, plant-based protein products are a dietary option, and they are unlikely to substitute regular meat and poultry products in the future. Animal meat is still in high demand throughout the world. However, meat will continue to be a major source of protein. Use phrases like "meat alternatives" or "meat substitutes" instead of sausages, burgers, and other meat-based items to guarantee a sustainable source of protein. There would be no confusion or unrealistic expectations. Scientists and food processors are trying to provide the most organic and nutrient-rich food possible from sustainably sourced plant protein sources to keep up with the world's population growth. However, the research should be focused to develop new methods to reduce product expenses.

Ethical statement - studies in humans and animals

The current manuscript entitled "Plant-based meat alternatives: compositional analysis, current development and challenges" is a review article and does not carry any original research on humans and animals.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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