IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

A review on faux meat

Authors

A Samiksha Sharma

Department of Food Technology , Lovely Professional University , Phagwara , India,

B Arsh Guleria

Department of Food Technology , Lovely Professional University , Phagwara , India,

C Lucky Barti

Department of Food Technology , Lovely Professional University , Phagwara , India,

1 .Abstract

A meat analogous is a meat substitute of meat for people consuming vegan products . It is also called as faux-meat ,mock meat,vegan meat ,meat alternative which contains the characteristics ie.flavour , texture,colour,taste,nutrition same as the meat. Meat is always considers as the product having high protein content and good nutrition benefits as well,which is beneficial for human health.But on the other hand vegetarian people are not able to consume it. The plant based protein are consumed by people since many years and the studies have been taken to make it better and nutritive. Developing a new food products for vegan to the consumers is a challenge. However, it is even more complex when these new foods to develop is an meat substitute products that are highly appreciated and accepted, like meat. This challenge was accepted by many developers to develop new sustainable meat substitutes to reduce the negative environmental impact of industrial-scale meat production for human consumption. Due to the animal diseases, global shortage of animal protein, global warming the demand and need of plant based protein has increased, Happily there is an increasing importance of legume, oil-seed proteins in the manufacturing of various functional food products due to their high-protein contents and texture. However, the greatest obstacle to utilize these legumes and oil-seeds is the presence of antinutrients present in them , though these can successfully removed or inactivated by employing certain processing methods. Legumes and oil-seeds provide well-balanced amino acid profiles when consumed with cereals ,Soybean proteins and other plant proteins have been used for preparation of meat analogues successfully.

Keywords: vegan meat, plant analogue, vegetarian, plant protein, vegan, meat alternative, protein rich food

2. Introduction

Since history, humans considered meat an essential part of their diet (Stanford & Bunn, 2001). Meat consumption has been key for human evolution because it has been linked to the development and brain growth within prehistoric Homo sapiens (Williams & Hill, 2017). Products with the highest demand, are beef, pork and chicken also the United States and Australia topping the charts for the highest annual meat consumption (Ritchie, 2019). Because of an increase in global population and rapid economic development, the last two decades have shown 58% growth in the global demand for meat (Whitnall & Pitts, 2019). Approximately by 2018, 320 tonnes of meat was consumed worldwide (Whitnall & Pitts, 2019), and it is predicted that by 2027 the market will expand up to 15% (OECD/FAO, 2018). However, because of the inefficiencies of meat production as compared to crop harvesting and the negative impacts from meat consumption on human health have become a topic of concern in recent years (Godfray et al., 2018; Marinova & Bogueva, 2019). Due to these increasing concerns, food industries are looking for ways to introduce meat alternatives made from non-animal proteins, but with similar appearances, mouthfeel, and smells, to traditional meat, to consumer markets (Kumar et al., 2017; Malav, Talukder, Gokulakrishnan, & Chand, 2015). The food research community is currently looking into two major varieties of meat analogues, culture-based meats (also clean meat, in vitro meat) (Bhat & Fayaz, 2011; Hocquette, 2016) and plant-based meat, which is constructed from proteins extracted from plants with the appropriate structuring processes (Joshi & Kumar, 2015; Wild et al., 2014).

The global market for plant-based substitutes is projected to reach $85 billion (USD) by 2030, up from $4.6 billion (USD) in 2018 (Gordon et al., 2019). At the same time, while cell-based meat is not yet commercially available, research and development are proceeding rapidly. One think tank estimates that demand for beef and dairy products in the U.S. will shrink by

80–90% by 2035, driven largely by a projection that the cost of “modern protein foods” (including certain plant-based substitutes and cell-based meats) will be five times cheaper than existing animal proteins (Tubb and Seba, 2019). Although these estimates are speculative, and not necessarily supported by other industry experts, they emphasize the disruptive potential of meat alternatives on the animal agriculture sector.

Also, fungi-based meat alternatives such as Quorn™ products (Peregrin, 2002; Wiebe, 2004) and insect-based meat analogue products, including insect-based burgers from Coop (Swiss food retailer) and insect fortified burger from Bugfoundation (Germany food company)

(Ismail, Hwang, & Joo, 2020), have also been marketed in recent years.Culture-based meat is produced through tissue engineering techniques (Bhat & Bhat, 2011; Noor, Radhakrishnan, & Hussain, 2016). Currently, this in vitro technique has been used in a laboratory to artificially create a hamburger, as proof that the notion can be applied to the food industry . Interest in plant-based substitutes and cell-based meats—collectively referred to as meat alternatives hereafter—has grown rapidly over the past decade. While some consumers choose to avoid meat from farmed animals (hereafter “farmed meat”) or animal foods altogether, a growing number of people are replacing a share of their meat intake with "plant-based substitutes" that seek to approximate the texture, flavor, and/or nutrient profiles of farmed meat using ingredients derived from pulses, grains, oils, and other plants and/or fungi. These products may soon be joined by "cell-based meats" (also referred to as "cultured meat," "in-vitro meat," "lab-grown meat," "cellular meat," "cultivated meat," or "clean meat") grown from animal stem cells using tissue engineering techniques, which currently remain for the most part in the prototype stage of development.

(Dekkers, Boom, & van der Goot, 2018). Although processed fungi-based meat, such as burgers and sausages, has been available on the retail market for decades, the production process is relatively complex and requires high amounts of energy (Dekkers, Boom, et al., 2018). As for insect-based meat substitutes, the main hurdle for its development and production is the acceptance of consumers. Considering the technical robustness and scalability for the production, as well as the long consumption history of traditional processed plant-based protein foods (such as tofu and tempeh) in Asia, plant-based meat has the potential to become a mainstream product among all commercial meat alternatives. In fact, due to the recent development of various plantbased meat brands, such as Beyond Meat,
Impossible food, and Light life, public media has stated that 2019 has been the year of plantbased burgers.

3. Limitations / The environmental concerns of traditional meat production

Valuable resources, such as land, water, and energy, are needed for all food production; however, the efficiency, that is, a comparison of the food produced through the use of natural resources, is different for each food system (de Vries & de Boer, 2010; Gerben's-Leenes, Moll, & Uiterkamp, 2003; Reijnders & Soret, 2003). For instance, different livestock, such as ruminant and nonruminant animals, and the same types of livestock living under different systems, such as free-ranged versus caged environments, have different energy requirements (Fu et al., 2015; Herrero et al., 2013). Although technology development in these meat production processes can help to achieve higher efficiency (Castellini, Boggia, Paolotti, Thoma, & Kim, 2012; Fu et al., 2015), they are still much less energy efficient than the growth and harvesting of plants (Pimentel & Pimentel, 2003; Reijnders & Soret, 2003). For instance, a significant quantity of crops such as grains and fossil fuels is needed to use as feed and to power the farm facilities required to maintain livestock (Sabate & Jehi, 2019). Traditional meat production is considered an intrinsically inefficient process since over 70% of the energy used during production is either lost through excrements or is consumed during animal body growth and development (Djekic, 2015; Röös, Sundberg, Tidåker, Strid, & Hansson, 2013). Using data obtained from published life cycle assessment (LCA) studies and other sources, Rei- jnders and Soret (2003) summarized that the land use, water requirement, fossil fuel requirement, and phosphate rock requirement for meat protein food production are several or even a dozen times higher than for soybean-based protein foods.
Reijnders and Soret (2003) also summarized that the emission of acidifying substances, biocides, and copper from meat protein food production is also higher than that from soybeanbased protein food production, especially the emission of copper, which is over 100 times higher. Along with the inefficient utilization of natural resources during meat production, the process acts as a source of serious environmental damage. Due to this, each life stage of meat products has been widely studied and evaluated through the LCA for their

resulting consequences on the ecosystem. Published LCA studies of the environmental impacts from livestock products have been well summarized and further reviewed by several scholars. Accord- ing to the evaluation of de Vries and de Boer (2010), beef requires the most resources for production and is the largest contributor to global warming of all the other animal products on the market. The greenhouse gas (GHG) emissions from animal and crop products, which were expressed as CO2 equivalents (CO2-Ceq), were reviewed by Tilman and Clark (2014), according to a total of 555 LCA analyses. It indicated that plant-based foods have lower GHG emissions than animal-based foods. The study further outlined that legume production causes approximately 250 times fewer emissions than ruminant meat, such as beef and lamb.

A systematic review has indicated that dietary change is an effective approach to reduce GHG emissions and also land use demand (Hallström, Carlsson-Kanyama, & Bör-Jesson, 2015). For example, a vegan diet can achieve 25% to 55% reduction of GHG emissions and 50% to 60% reduction of land use demand, and partially replacing meat by plant-based food can also reach about 5% reduction of GHG emissions and 15% reduction of land use demand (Hallström et al., 2015). Van Mierlo, Rohmer, and Gerdesse (2017) once conducted a study to select a suitable meat replacer that poses similar nutritional value but lower environmental impact. Four types of modelled meat replacers, including vegetarian, vegan, insect-based, and fortificationfree, were compared, and the result indicated that vegan replacers can reduce up to 87% of indicators such as climate change, land use, and fossil fuel depletion (Van Mierlo et al. 2017). Fresán and Sabaté (2019) also estimated that progression from current omnivore diets to vegan and ovo-Lacto vegetarian diets can achieve about 50% and 35% decrease of GHG emissions, respectively. Therefore, shifting the global food production system to more sustainable means by focusing on plant-based alternatives will help to protect limited natural resources and ensure that a sustainable environment can be maintained for human survival.

3.1Techniques for creating meat-like appearance and flavour

The first element to be noticed for a food product is colour; hence, it is the main contributor to the perception in taste and overall product acceptance by consumers (Spence, 2015). Normally, raw fresh meat poses a red colour that turns brown upon cooking. Meat analogues should strive to obtain an identical appearance to real meat by mimicking both the initial colour and the resulting colour changes during cooking. However, most plant-based protein elements, such as gluten and soy, are originally yellow or beige (Kyriakopoulou et al., 2019). Within the first generation of PBMA, the browning technique of meat was copied by using colouring ingredients or adding precursor substances. Caramel colours and malt extracts are typical heat-stable colouring ingredients that can provide the final product with a brown appearance (Kyriakopoulou et al., 2019; Malav et al., 2015). Additionally , reducing sugars can be added as browning agents as they are capable of forming brown substances during cooking through Maillard reaction with the amine groups in protein (Rolan et al., 2008). In the new generation of PBMA, the red colour of raw products has been obtained through the addition of beet juice/powder or soy leghemoglobin (Bohrer, 2019). The thermal stability and pH sensitivity of the colouring agents are of great importance for their successful application in PBMA (Kyri- akopoulou et al., 2019). Thermally unstable colouring agents will degrade during the cooking process and may bring about an unacceptable colour appearance. To ensure that the colouring effect is optimal, the pH range of a given colouring agent should match that of the meat analogue. Colouring agents can either be mixed with the protein products before the structuring process or they can be integrated with the semistructured plant-based materials during the structuring process (Kyriakopoulou et al., 2019). Moreover, hydrated alginate and maltodextrin are two examples of colouring agent additives that aid in retaining the desired colour by reducing the colour migration within the final product (Kyriakopoulou et al., 2019; Richards, Hargrove, Erazo-Castrejon, & Alagurajan, 2019). Despite the numerous colouring agents and application methods available in the food industry, the overall colour appearance of PBMA remains low in quality. Further research is needed to more effectively resemble the colour of both raw and cooked meat.

Food flavour is another influential element that plays a significant role in product acceptance (Kim, Yang, & Chung, 2017). The process of flavour formation is considerably more complex than colour formation, and flavouring agents can be divided into volatile and nonvolatile compounds that are related to the aroma and taste, respectively. Meat has an umami taste, which mainly originates from the presence of monosodium glutamate and inosine monophosphate, as well as various small organic acids (Kyriakopoulou et al., 2019). In contrast, it has been determined that wide assortments of compounds are related to the aroma of meat products (Aaslyng & Meinert, 2017). When heat is applied, these compounds mainly form via Maillard reactions and lipid degradation (Aaslyng & Mein- ert, 2017). Due to the complexity of the compounds associated with the fragrance of meat, it has proven to be quite challenging to mimic the aroma of meat in PBMA (Kumar et al., 2017; Kyriakopoulou et al., 2019). Although Mail- lard reactions and lipid degradation can also be carried out during the cooking of PBMA, the slight differences that exist between the reactions in PBMA and meat products cause a great variance of the resulting aroma compounds (Kumar et al., 2017). Also, raw meat only requires one thermal treatment for consumption; however, PBMA requires much more intricate treatments. During the structuring process, high heat and pressure are required and the cooking of PBMA involves further heat treatments. Our analysis of flavour compounds demonstrated a significant difference between beef burgers and the first and new generation of plantbased burgers (data unpublished). Although it is difficult, there has been some progress in the flavour mimicking process of PBMA. It has been demonstrated that the addition of aromatic ingredients such as spices and salt to plant-based food mixtures both before and after the extrusion process can help to generate flavourful and fragrant final products (Kyriakopoulou et al., 2019). Some of the additives that have helped to create the impression of aromatic meat in PBMA products include the vitamin thiamine, amino acids, and reducing sugars (Fraser, Brown, et al., 2018). Also, chicken- and beef-like fragrances have been produced from soybean-hydrolyzed protein under specific reaction conditions (Wu, Baek, Gerard, & Cadwallader, 2000). Nonetheless, additional research is required to further develop meat-like aromas in PBMA products.

3.2 The most important ingredient of meat analogues and traditional meat products Protein The protein components used for the manufacture of meat analogues is one of the most significant components for product identity and product differentiation. Proteins have vital structure-function relationships in terms of hydration and solubility, interfacial properties (such as emulsification and foaming), flavour binding, viscosity, gelation, texturization, and dough construction (S.J. Meade, E.A. Reid, J.A. Gerrard. The impact of processing on the nutritional quality of food proteins, S.

Damodaran, K.L. Parkin Fennema's Food Chemistry (fifth edition), CRC Press 2017). Furthermore, processing induced physical, chemical, and nutritional changes occur in proteins and are dependent on the protein origin (S. Damodaran, K.L. Parkin Fennema's Food Chemistry (fifth edition), CRC press 2017).There are numerous plant-based sources of proteins presently used in the manufacture of meat analogues. The emphasis of the remaining portion of this segment is to provide background knowledge on each of these sources of proteins and explore the nutritional implications of singleuse or the combination of single used ingredients. Animal-derived products contain a complete source of protein, which is defined as an adequate proportion of each of the nine indispensable amino acids necessary in the human diet and acceptable digestibility of these amino acids. Previous research efforts have established that while some plant-based food sources contain a completed source of protein, many are lacking or limiting in one or more indispensable amino acids (B.M. Bohrer Nutrient density and nutritional value of meat products and non-meat foods high in protein Trends Food Sci. Tech., 2017). Soy protein is historically the most widespread protein used in meat analogue products. Several research reviews have been used to form comprehensive studies on the positive, health-improving results of soy protein consumption with the advancement in lipid metabolism(C.W. Xiao Health effects of soy protein and isoflavones in humans J. Nutr., 138 (2008) and cardiovascular health (F.M. Sacks, A. Lichtenstein, L. Van Horn, et al. Soy protein, isoflavones, and cardiovascular health: an American Heart Association Science Advisory for professionals from the Nutrition Committee Circulation., 2006).

Legume proteins (i.e. pea, lentil, lupine, chickpea, mung bean, and others) are attaining popularity among the manufacturers of meat analogues in modern years. Kyriakopoulou et al. (2019) examined the promising application of pea protein when structured with high-moisture extrusion (K. Kyriakopoulou, B. Dekkers, A.J. van der Goot Plant-based meat analogues Sustainable Meat Production and Processing, Academic Press 2019) Nutritionally speaking, legume proteins are normally low in methionine and are greatly affected by challenges with digestibility (mainly antinutritional factors) (M.G. Nosworthy, J.D. House Factors influencing the quality of dietary proteins: implications for pulses Cereal Chem., 94 2017). While it is generally assumed that processing enhances availability and digestibility of proteins, the protein digestibility corrected amino acid scores (PDCAAS) of unprocessed legumes products are generally in the 0.40 to 0.70 range, which is not comparative to animal-derived proteins or processed soy protein (S. Huang, L.M. Wang, T. Sivendiran, et al. Amino acid concentration of high protein food products and an overview of the current methods used to determine protein quality Crit. Rev. Food Sci. Nutr., 58 2018) From a functional viewpoint, legume proteins offer a great complementary advantage to other protein ingredients with many promising and unique processing attributes (K. Kyriakopoulou, B. Dekkers,
A.J. van der Goot
Plant-based meat analogue substainable Meat Production and Processing, Academic Press 2019)

4. Challenges of artificial meat production

Prospects to generate artificial meat are apparently optimistic, however, there are numerous challenges and pitfalls. The most important are epidemiology and economy issues. There is urgent need to develop commercial technology for culturing meat reasonably prized and free of any hazard of animal-born disease (pros). Nutrition-related diseases, foodborne illnesses, antibiotic-resistant pathogen strains, use of resources and farm animals, environmental repercussions of raising livestock, including pollution from their excrement and massive emissions of methane contributing to global warming are some of the serious consequences associated with conventional meat production systems and consumers have expressed growing concern over them (Bhat and Bhat 2011a, b, c; Bhat et al. 2013) There are a lack of animal meat flavor that consumers are familiar with and expect is another major hurdle to the progress of alternative products (Graça, Godinho, &

Truninger, 2019).Although, it seems to be speculative at the moment, one might adopt biotechnology methods based on bioreactors coupled to dialysing systems. It would allow for continuous growth of muscle cells in semi-open system. Muscle cells could be propagated and recovered for further steps of differentiation into muscle fibers in aseptic conditions. Similarly, other components of meat could be managed. Adiposities are successfully produced from adipose tissue derived stem cells (ADC), or from other mesenchymal cells (fibroblasts). The latter cells can easily be isolated through skin biopsy. Materials used to grow cells in culture are rather expensive and some of them are of animal origin (sera) having risk of contamination (cons). Beside, it would be hard to use term "cruelty-free meat" if muscle tissue is grown on sera collected from fatal or newborn calves. The answer could be a synthetic substitute (mixture of substances that mimic serum activity) or natural product of plant origin with identical assets as serum. Affordable prize of growth media can be achieved when large volumes are produced and system is semi-open as it is in dialysed bioreactors (pros).

4.1The Promises of Meat Alternatives

There are a variety of alternatives exist to approximate or even replicate certain aspects of meat's texture, flavor, and/or nutrient profile. These range from natural foods that resemble certain characteristics—not necessarily nutritional—of meat (e.g., pulses, mushrooms, jackfruit), to products that are not designed to mimic meat but can be used in similar ways (e.g., tofu, tempeh, seitan, bean burgers), to more processed products that are designed to imitate the experience of eating certain meat products (e.g., meat-like burgers, hot dogs, fish filets) (Lagally et al., 2017).

Products in the last category have been gaining particular momentum over the past decade, with new technological advances aimed at replicating selected characteristics of meat down to the molecular level. Several products are designed to be "viscerally equivalent" to farmed meats in order to appeal to those who enjoy meat (Stephens et al., 2018). Most of these plant-based substitutes use soy, wheat, or pea protein isolates or concentrates as their primary protein source, though products derived from fungi (i.e., mycoprotein) and lupin beans also exist. Examples of common plant-based substitute brands and products include Gardein Meatless Meatballs, Morningstar Farms Original Chik Patties, Beyond Meat's Beyond Burger and Impossible Foods' Impossible Burger (see Table S3). A rapidly growing number of companies are also aspiring to produce cell-based meats that are not only viscerally equivalent but also "biologically equivalent" to farmed meat through cultivation of animal cells (Stephens et al., 2018). The technological feasibility of replicating the exact structure, texture, color, flavor, and nutritional composition of farmed meat, however, remains in question. Replicating these characteristics for fresh, unprocessed meat would require several particularly complex technical feats, including simulating the role of blood in delivering oxygen and nutrients throughout thicker pieces of tissue, as well as co-culturing fat, muscle, and connective tissues (Fraeye et al., 2020).

Meat alternatives are promoted for their environmental, animal welfare, and in some cases, public health benefits. "Eat Meat. Save Earth," is the mission proclaimed on Impossible Foods' website (Impossible Foods, 2020), accompanied with statistics comparing the land, water and GHG emissions associated with an Impossible Burger and a conventional beef burger. Popular press echoes these messages about how "Fake

Meat Will Save Us" (Egan, 2019). As one journalist states: "Farmfree food will allow us to hand back vast areas of land and sea to nature, permitting rewilding and carbon drawdown on a massive scale. It means an end to the exploitation of animals, an end to most deforestation, a massive reduction in the use of pesticides and fertilizer, the end of trawlers and longliners" (Monbiot, 2020). Cell-based meat is also purported to be "healthier, safer, and disease-free" compared to farmed meat (Arshad et al., 2017). Notably, these claims are most often compared to beef, which generally has the largest environmental impacts among animal products.

The extent to which meat alternatives achieve these purported benefits depends in part on several factors, including the specific ingredients or inputs used to produce them (Figures 1, 2), the extent to which consumers accept and incorporate these products into their diets, and which farmed meats they are replacing (e.g., beef vs. poultry, conventional meat vs. meat from agroecological production systems), if any. Thus, in the following sections, we compare the impacts of meat alternatives to a variety of farmed meats. Although several literature reviews have examined trends in consumer perceptions about and theoretical willingness to try meat alternatives (Hartmann and Siegrist, 2017; Bryant and Barnett, 2018; Weinrich, 2019), the studies underlying these reviews may be outdated given the influx of new plant-based substitutes into the market and demonstrated consumer acceptance in the past few years [International Food Information Council (IFIC), 2020; McCarthy and DeKoster, 2020]. As cell-based meats enter the marketplace, consumer perceptions and acceptance may also change. We also recognize that potential public health, environmental, and animal welfare benefits associated with meat alternatives would only occur if demand for those products offsets a share of farmed meat production, rather than simply adding to the combined total production of farmed meat and meat alternatives (Stephens et al., 2018). Given the importance of consumption patterns on the potential benefits associated with meat alternatives, we call for additional research in Appendix B (Supplementary Material) to better understand how consumers are incorporating these products into their diets.

It is worth mentioning that since cell-based meat has not yet been commercialized, existing research about its production is based on a few anticipatory life cycle assessments (LCAs) which assumed hypothetical inputs, production processes, and technological advances (Tuomisto and Teixeira de Mattos, 2011; Tuomisto et al., 20141; Mattick et al., 2015b). Some researchers have noted that several assumptions and simplifications made in these LCAs are not supported by existing scientific evidence and should be interpreted carefully (Lynch and Pierrehumbert, 2019; Thorrez and Vandenburgh, 2019). For instance, the presented LCAs covered in this review assumed that the cellbased meat would be grown without fetal bovine serum, a reality that remains one of the industry's biggest . Nevertheless, we include those studies' results, since it is the most detailed information about the potential inputs and implications of cell-based meat production. After given the limitations of existing research, it is of critical importance that ongoing, independent, and comprehensive multi-product environmental analyses are conducted as the technologies and commercial operations for meat alternatives develop and scale (Mattick et al., 2015a).

Many plant-based seafood alternatives use soy, wheat, or pea protein isolates as their primary protein source (Table S4) and are comparable to plant-based terrestrial meat substitutes. Some products on the market are not designed to mimic seafood exactly but can be used in similar ways (e.g., products made from carrots, eggplant, or tomatoes); these are not examined in this review. Additionally, while the term "seafood" includes sea vegetables (e.g., seaweed, algae)—some of which may have high concentrations of protein and micronutrients (Fleurence et al., 2012)—their impacts are not assessed here. Cell-based seafood products are also in development, though the regulatory pathways and markets will likely be different than those of cell-based terrestrial meats.

Lastly, while this review primarily compares meat alternatives to the farmed meats for which they are intended to substitute, meeting dietary protein needs does not necessarily require consumption of either group of products. Producing and consuming other protein-rich foods, such as minimally processed legumes (including soybeans, lentils, beans, and peas) and insects, should be considered as part of the path forward for sustainable food systems.

5. Health benefits of vegan meat

Vegan diets consists of food products which are higher in dietary fiber, magnesium, folic acid, vitamins C and E, iron, and photochemical, and which basically tends to be lower in calories, saturated fat and cholesterol, long chain n–3 (omega-3) fatty acids, vitamin D, calcium, zinc, and vitamin B-12 . In general, vegetarians food is basically a lower risk of cardiovascular disease (CVD), obesity, type 2 diabetes and some cancers . A vegan diet appears to be useful for increasing the intake of protective nutrients and photochemical and also useful for minimizing the intake of dietary factors implicated in several chronic diseases . In a recent report , different plant food groups were rated with respect to their metabolic epidemiologic evidence for influencing chronic disease reduction. According to the evidence criteria of the World Health Organization and Food and Agriculture Organization (WHO/ FAO), cancer risk reduction associated with a high intake of fruit and vegetables was assessed as probable or possible, risk of CVD reduction as convincing, whereas lower risk of osteoporosis was assessed as probable . The evidence for a risk reducing effect of consuming whole grains was assessed as possible for colorectal cancer and probable for type 2 diabetes and CVD. The evidence for a risk-reducing effect of consuming nuts was assessed as probable for CVD .

5.1 Valuable Nutrients

Many studies – for example those conducted by the World Health Organization (WHO) – show that a vegan diet is associated with many health benefits. The attribute of taste (including mouthfeel) is critical to the motivation of regular meat consumers to modify their diet behavior by reducing meat consumption (Tuorila & Hartmann, 2020). The absence of fatty meat alone almost always has a positive health effect. Since the diet of vegans is based on plants, vitamin-rich vegetables, fresh salads, and nuts containing high-quality fats and proteins, the vegan diet provides many different vitamins and nutrients. Moreover, vegan food does not automatically lead to malnutrition because vegetables are often rich in nutrients. Additionally, the vegan diet contains many dietary fibres and micronutrients such as secondary plant substances and antioxidants as well as vitamins and minerals such as magnesium, potassium, and folic acid.

5.2 Proteins and Fats: Comparison of Vegetable and Animal Sources

Proteins are the basic components of our body. This especially applies to essential amino acids. Meat and dairy products are the number one source of such essential amino acids. Proteins are also necessary for muscle building and maintenance. Athletes, in particular, may fear that a vegan diet represents a disadvantage in this respect. However, you can also build muscle with vegetable proteins as long as they contain all essential amino acids. This is the case with legumes, nuts, whole grains, soy products, and also some vegetables. These foods also offer a key health benefit: Plant protein sources usually contain less fat and cholesterol than animal sources. The situation is similar with fats. Vegetable products contain significantly more unsaturated fatty acids. These so-called good fats lower cholesterol levels. However, hydrogenated vegetable fats, such as those found in margarine, are not considered good fats.

5.3 Slimming Effect

One key question is whether if someone who is living a vegan lifestyle has an advantage or disadvantage in losing weight? Several studies have already investigated this question. Statistics on the body mass index of vegans suggest that vegans are often thinner. Additionally, vegan diets have proved to be more nutritionally efficient than mixed diets. This is due to the fact that vegan foods tend to contain more fibre and less fat. However, this does not apply to crisps, chips, and soft drinks. Vegetable snacks such as crisps and chips are some of the unhealthiest fatteners of all. Prevention of Disease It usually reduces the risk of common diseases. Because those who follow a vegan diet build up fewer fat deposits, absorb a wider range of nutrients, and do not eat meat containing high amounts of cholesterol, they are less susceptible to cardiovascular diseases and Type 2 Diabetes.

The Heidelberg vegetarian study conducted by the German Cancer Research Centre has also shown that the avoidance of red, processed meat can significantly reduce the risk of cancer. What these studies do not show, however, is the influence on one's lifestyle. For instance, it has been demonstrated that most vegans also drink less alcohol, smoke less often, and exercise more than average.

6. Food Safety

Many of the plant-based substitutes contain at least one major food allergen among their ingredients, with wheat and soy being the most common [Food Drug Administration (FDA), 2004]. Individuals allergic to peanuts and soy may also experience reactions to pea and lupin protein, though this is rare (Lavine and Ben-Shoshan, 2019). Allergic and gastrointestinal reactions to mycoprotein-based plant-based substitutes (e.g., Quorn) have also been reported; though rare, the incidence of adverse reactions to mycoprotein in the general population is debated (Jacobson and DePorter, 2018; Finnigan et al., 2019). Individuals with intolerances to certain food additives and gums must also be careful given their prevalence in plant-based substitutes.

Carrageenan, for example, is a structural ingredient derived from seaweed that is commonly used in plant-based substitutes and other processed foods for purposes of thickening, gelling, or stabilizing. The safety of carrageenan has long been debated, with attention being focused on its potential to elicit gastrointestinal inflammation, alterations to intestinal microflora, and other related outcomes such as irritable bowel syndrome and colon cancer (Bixler, 2017; David et al., 2018). In addition to that , because carrageenan is grown in seawater, it has the potential to accumulate significant concentrations of heavy metals (Almela et al., 2002; Besada et al., 2009), though no research has characterized exposures to arsenic, cadmium, lead, and mercury that result from consumption of carrageenan-containing foods.

Some concerns have also been raised about the safety of new additives present in some plant-based substitutes, such as mycoprotein used in Quorn products and soy leghemoglobin used in Impossible Foods products. See Policy Implications for a discussion of the approval processes and regulatory debates.

Some propose that if cell-based meat were produced under sterile conditions, it could reduce the incidence of foodborne illness (Bhat and Bhat, 2011). By not involving the processing of whole animal carcasses, cell-based meats would likely reduce the potential for contamination that exists in farmed meat handling and processing, such as Escherichia coli contamination from contact with digestive organs and feces. However, fully sterile conditions would be near impossible to achieve and thus antibiotics would likely be required as inputs for the tissue culture medium in order to inhibit the growth of bacterial pathogens (Stephens et al., 2018; Thorrez and Vandenburgh, 2019). The exact nature of antibiotic use in this context is not yet known, though the quantities and regularity of use would likely be lower than in industrial livestock operations. Transmission of zoonotic diseases may decline if cell-based meat production reduced human-livestock interactions (Bhat and Bhat, 2011; Arshad et al., 2017), though more research on this potential is merited.

7. **The structuring process of plant-based proteins**

The structuring process is the most important step for plant based meat alternative production because it is the foundation of meat-like texture formation. The characteristic and dominant feature of consumable meat is its fibrous structure and texture (Listrat et al., 2016); thus during PBMA production, the structuring process aims to develop a fibrous structure by plant-based protein. The techniques used during the structuring process for the formation of different meat analogues, including both reputable techniques that have been incorporated into the food industry as well as newly developed procedures, have been well summarized by Dekkers, Boom, et al. (2018). These processing techniques can be divided into two strategies, bottom-up and top-down. Within the bottom-up methodology, each structural component is combined to generate the final PBMA product, whereas with the top-down procedure, a fibrous texture is created through the formation of a biopolymer blend. Among these techniques, commercial operations for PBMA processing often use the top-down strategy extrusion, due to its robustness and ability to mass produce on a large scale (Kinney et al., 2019). However, other newly developed top-down strategies such as shear cell technology are still on the pilot scale (Krintiras, Diaz, Van Der Goot, Stankiewicz, & Stefanidis, 2016; Krintiras, Göbel, Van der Goot, & Stefanidis, 2015). Other techniques such as wet spinning (Rampon, Robert, Nicolas, & Dufour, 1999), electrospinning (Miyoshi, Toyohara, & Minematsu, 2005), mixing with hydrocolloids (Kweldam, 2011), and ice/freeze structuring (Hassas-Roudsari & Goff, 2012) are also applied to the structuring of plant-based protein, but only at the research stage. Among each of the techniques, sheer cell and extrusion are among the most practical options for future PBMA production, whereas the others are either of higher environmental impact or less robust (Dekkers, Boom, et al., 2018).

Extrusion is a well-developed technology in the food industry (Maskan & Altan, 2016). It was first designed to manufacture pasta products during the 1930s (Berk, 2018; Sevatson & Huber, 2000). This process involves the transformation and molding of food products by driving them through a die, applying heat and pressure, and using a mechanical shear to obtain the desired sizing (Maskan & Altan, 2016). A typical extrusion process can be divided into three steps, that is, the initial preparation of the food material before the addition into the extruder, the ingredients are then cooked and mixed together to obtain a homogeneous texture within the barrel of the extruder, and finally the resulting product is left to cool in a die to maintain its final shape (Kyriakopoulou, Dekkers, & van der Goot, 2019). During the early stages, only low-moisture extrusion in single-screw extruder was utilized for the production of dry and expanded TVP products that can soak up water due to their sponge-like organizations (Kinney et al., 2019). In the early 1980s, twin-screw extruders that were more advantageous than the single-screw counterpart were developed (Sevatson & Huber, 2000). Twin-screw extruders could achieve higher energy efficiency and more consistent heat distribution (Van Zuilichem, Stolp, & Janssen, 1983). In addition, twin-screw extruders possess more versatility that can achieve the production of meat analogues by high-moisture extrusion, a technique used to manufacture fibrous products with at least 50% moisture by hydrating the food mixture during the extrusion process (Kinney et al., 2019; Wang et al., 2019). Comparing to products manufactured by low-moisture extrusion, high-moisture extruded plant-based protein can obtain well-defined fiber structure and enhanced visual appearance and mouth feel (Pietsch, Emin, & Schuchmann, 2017; Yao, Liu, & Hsieh, 2004).

Additional reviews on the impacts of the various parameters of extruder operation, such as the temperature within the barrel and the screw speed, on products using soy and pea proteins as the main ingredients have been carried out (Chen, Wei, Zhang, & Ojokoh, 2010; Lin, Huff, & Hsieh, 2002; Pietsch et al., 2017; Rehrah, Ahmedna, Goktepe, & Yu, 2009). The quality of the final product is determinate by a group of process parameters, hence multi-factor experimental design, such as response surface methodology, was mainly used for the optimization of extrusion process of different plant-based protein sources (Omohimi, Sobukola, Sarafadeen, & Sanni, 2014; Rehrah et al., 2009). Several studies have found that the texturization of the final product is heavily dependent on the temperature of the extrusion process (Kyriakopoulou et al., 2019). For instance, to create the fibrous texture through cross-linked reactions, specific melting temperatures must be carefully chosen (Kyriakopoulou et al., 2019). Additionally, a higher barrel temperature can help to enhance the expansion, contraction, and the water absorption of the final products (Kyriakopoulou et al., 2019). In comparison to the moisture content and temperature, most studies revealed that screwspeed is a minor impact factor to the quality of the final PBMA (Omohimi et al., 2014; Rehrah et al., 2009; Samard, Gu, & Ryu, 2019). In addition, the percentage of soluble and insoluble components within the ingredients is also very significant for the structure formation, as the crosslinking of proteins is prevented by high portions of insoluble compounds (Dekkers, Boom, et al., 2018). In early stage, the process and design involved with extrusion production was largely relied on empirical knowledge (Dekkers, Boom, et al., 2018; Kyriakopoulou et al., 2019). However, attention to the precise mechanism for the formation of the fibrous structure in extrusion has been increased in recently years. Mechanisms of the texturization of soy and pea proteins have been discussed and summarized by several research teams (Murillo, Osen, Hiermaier, & Ganzenmüller, 2019; Samard et al., 2019).

The extrusion technique is widely used by the food industry as it permits for the mass production of meat analogues with high energy efficiency. However, shear cell technology is a more energyefficient structuring process that was introduced about a decade ago (Grabowska et al., 2016; Manski, van der Goot, & Boom, 2007). This procedure, which was inspired by the effect of shear flow on dough, has been found to be effective for the production of meat analogues when functioning at raised temperatures (Grabowska et al., 2016). Shear-induced structuring can be achieved with small size shear cell (Krintiras et al., 2015) or through the use of a Couette Cell (Krintiras et al., 2016). The Couette Cell procedure can be accomplished through treatments involving heat and simple shear; however, the final structure of the meat analogue is determined by its composition as well as the set conditions during production, such as the process temperature, process time, and the shear rate. Structured products of several plant-based materials, including soy protein concentrate (Grabowska et al., 2016), soy protein isolate (SPI)–WG blends (Dekkers, Emin, Boom, & van der Goot, 2018; Schreuders et al., 2019), and SPI–pectin blends (Dekkers, Hamoen, Boom, & van der Goot, 2018), have been successfully achieved through this technology.

Depending on the processing conditions, fibrous, layered, or homogeneous samples can be obtained; however, fibrous structures are optimal due to consistently higher anisotropy indices. Similar to the extrusion technology, several studies have also demonstrated that the processing temperature is the most important parameter for shear-induced structuring (Kyriakopoulou et al., 2019). In a lab-scaled study where SPI-WG was used as the raw material, Krintiras et al. (2015) demonstrated that the optimum processing conditions for enhanced fiber structure formation included processing for 15 min, then rotating the raw materials at 30 RPM, and finally, heating the mixture at 95 °C. During another up-scaled study by Krintiras et al. (2016), a final product with 30-mm thickness was obtained through shear-induced structuring. However, meat analogues produced through the extrusion process can typically obtain a final thickness of only 5 to 10 mm. Therefore, although shear cell technology is still on the pilot scale, it brings about new opportunities to improve the flexibility in product shape.

7.1 Techniques for creating meat-like appearance and flavor

Color is often the first element to be noticed for food products; hence, it is a main contributor to the perception in taste and overall product acceptance by consumers (Spence, 2015). Generally, uncooked fresh meat poses a red color that turns brown upon cooking. Meat analogues should strive to obtain a similar appearance to real meat by mimicking both the initial color and the resulting color changes during cooking. However, most plant-based protein ingredients, such as gluten and soy, are originally yellow or beige in nature

(Kyriakopoulou et al., 2019). Within the first generation of PBMA, the browning process of meat was replicated by using coloring ingredients or adding precursor substances. Caramel colors and malt extracts are typical heat stable coloring ingredients that can provide the final product with a brown appearance (Kyriakopoulou et al., 2019; Malav et al., 2015). Additionally, reducing sugars can be added as browning agents as they are capable of forming brown substances during cooking through Maillard reaction with the amine groups in protein (Rolan et al., 2008). In the new generation of PBMA, the red color of raw products has been obtained through the addition of beet juice/powder or soy leghemoglobin (Bohrer, 2019). The thermal stability and pH sensitivity of the coloring agents are of great importance for their successful application in PBMA (Kyriakopoulou et al., 2019). Thermally unstable coloring agents will degrade during the cooking process and may bring about an unacceptable color appearance. To ensure that the coloring effect is optimal, the pH range of a given coloring agent should match that of the meat analogue. Coloring agents can either be mixed with the protein products before the structuring process or they can be integrated with the semistructured plant-based materials during the structuring process (Kyriakopoulou et al., 2019). Moreover, hydrated alginate and maltodextrin are two examples of coloring agent additives that aid in retaining the desired color by reducing the color
migration within the final product (Kyriakopoulou et al., 2019; Richards, Hargrove, ErazoCastrejon, & Alagurajan, 2019). Despite the numerous coloring agents and application methods available in the food industry, the overall color appearance of PBMA remains low in quality. Further research is needed to more effectively resemble the color of both raw and cooked meat.

Food flavor is another influential element that plays a significant role in product acceptance (Kim, Yang, & Chung, 2017). The process of flavor formation is considerably more complex than color formation, and flavoring agents can be divided into volatile and nonvolatile compounds that are related to the aroma and taste, respectively. Meat has an umami taste, which mainly originates from the presence of monosodium glutamate and inosine monophosphate, as well as various small organic acids (Kyriakopoulou et al., 2019). In contrast, it has been determined that wide assortments of compounds are related to the aroma of meat products (Aaslyng & Meinert, 2017). When heat is applied, these compounds mainly form via Maillard reactions and lipid degradation (Aaslyng & Meinert, 2017). Due to the complexity of the compounds associated with the fragrance of meat, it has proven to be quite challenging to mimic the aroma of meat in PBMA (Kumar et al., 2017; Kyriakopoulou et al., 2019). Although Maillard reactions and lipid degradation can also be carried out during the cooking of PBMA, the slight differences that exist between the reactions in PBMA and meat products cause a great variance of the resulting aroma compounds (Kumar et al., 2017). In addition, raw meat only requires one thermal treatment for consumption; however, PBMA requires much more intricate treatments. During the structuring process, high heat and pressure are required and the cooking of PBMA involves further heat treatments. Our analysis of flavor compounds demonstrated a significant difference between beef burgers and the first and new generation of plant-based burgers (data unpublished). Although it is difficult, there has been some progress in the flavor mimicking process of PBMA. It has been demonstrated that the addition of aromatic ingredients such as spices and salt to plant-based food mixtures both before and after the extrusion process can help to generate flavorful and fragrant final products (Kyriakopoulou et al., 2019). Some of the additives that have helped to create the impression of aromatic meat in PBMA products include the vitamin thiamine, amino acids, and reducing sugars (Fraser, Brown, et al., 2018). In addition, chicken- and beef-like fragrances have been produced from soybean-hydrolyzed protein under specific reaction conditions (Wu, Baek, Gerard, & Cadwallader, 2000). Nonetheless, additional research is required to further develop meat-like aromas in PBMA products.

7.2 The selection of plant-protein sources

The structure organization of PBMA is dependent on protein properties, such as the ability to retain liquids as well as its gelation and solubilizing capabilities (Dekkers, Boom, et al., 2018). In addition, different types of proteins can induce altered appearances, flavors, nutrition, and health impacts within the final product. Therefore, selecting a suitable protein source remains one of the key aspects for PBMA production. Currently, a wide variety of plant-based protein are used for the industrial manufacture of meat analogues, but soy and peas are the primary source due to low costs and the possession of some properties similar to meat (Kyriakopoulou et al., 2019). The quality of PBMA could be heightened by exploring new protein sources to partially or completely replace traditional protein alternatives. Asgar, Fazilah, Huda, Bhat, and Karim (2010) and Jones (2016) have previously discussed the potential of nonmeat proteins as the main ingredients for meat analogues through the analysis of various functional and nutritional properties. According to the summarized data, proteins obtained from legumes such as chickpeas and soybeans are ideal for PBMA production due to their functional properties, whereas proteins from insects and zein are among the most cost-efficient options (Jones, 2016). Additional studies have concluded that oilseeds provide an adequate source of amino acids, particularly when paired with dry foods such as cereal (Asgar et al., 2010).

Chiang, Loveday, Hardacre, and Parker (2019) have determined that PBMA blends with 30% WG mixed with soy protein produce the closest physiochemical properties to meat. Thus, this discovery demonstrated the potential of WG as a protein source in meat alternatives. Moreover, many research groups have drawn their interests toward microalgae spirulina (Arthrospira platensis), which can be suitable as a meat alternative due to its high levels of protein. The results of Grahl et al. (2018) indicated that supplementing 30% to 50% spirulina to soy protein still can obtain well-structured final products, although increased amount of spirulina will induce a negative impact on the flavor. Caporgno et al. (2020) further demonstrated that reducing moisture levels in the final product could help the formation of the fibrous structure when up to 50% microalgae biomass has been added. Generally, adding small amount of microalga to the PBMA products is a desirable option. Mushroom is technically not a plant, but it is another great option for meat analogue production, due to the fact that mushrooms are rich in sulfur-containing amino acids, which can help to achieve a meaty flavor (Kumar et al., 2017). In addition, mushrooms are rich in biological activity components, which can provide many health benefits, including antitumor potential (Rathore, Prasad, & Sharma, 2017).

Some waste biomasses pose as a potential source of protein for PBMA due to the high levels of protein present. For example, Zhang, Liu, et al. (2019) was successful in utilizing peanut protein biomass waste with high-moisture extrusion to produce meat analogues. This method is highly desirable as it helps to reduce waste products and aids to decrease the amount of resources needed for food production. Additionally, the commercialization of edible insects and insect-based meat alternatives has begun in Western countries, along with the gradual acceptance by a number of consumers (Megido et al., 2016). As there may be difficulties in mass producing insect-based meat alternatives to fulfill global market requirements, a solution could include partially incorporating insect-based protein into PBMA.

8. Materials and methods used till date for different vegan meat preparation

The number of studies have take place by the scientists all over the world to make the vegan meat with the same amount of the nutritional quality as well as the taste. The making of vegan meat has been started a long time back , by performing the experiments required to sustain the quality. After many years of research the food industries naming Impossible Foods Inc and Beyond Meat are able to produce the good quality vegan meat .

8.1. Impossible meat-

8.1.1. Procedure of preparation

The main key ingredients of impossible burger is heme and it is prepared in the lab with the help of beetroot including the fermentation process. All the materials i.e.- soy protein(Tenderized soy beans are used as it gives high protein and good texture), potato protein(act as an binding agent, after cooking it gels up to hold water and make it juicy), flakes of coco nut oil(traps all the delicious flavour of all the ingredients), heme (the key ingredient) , fats (traps the flavour and helps to bind up together)are prepared and measured in premixing area and mixed in the giant mixer.Then the formation of the patty begins, with the help of moulder the patty gets its shape and is directly passed to the freezer to protect it prom spoilage and after sometime the patties are packed and transfered to the different places

8.2. The Beyond Meat - Soybean and pea proteins based-

8.2.1. Preparation Variety of plant proteins i.e. pea,mung bean, faba bean, brown rice are mixed in according the precised amount ,then the fat sources are added to provide the juiciness i.e. coca butter,coconut oil, Expeller-Pressed Canola Oil , to make the nutritional content equal to meat calcium ,iron ,salt,potassium ,chloride and yeast extract which addes vitamin b as well as the flavour .For the proper color and favour beet juice extract ,apple extract ,natural flavors are added and to hold all these ingredients potato starch and methyl-cellulose a plant fiber derivative is added. A natural emulsifier is added to provide right amount of texture At the end calcium alginate is used which is a plant based casing made with seaweed .

8.3. Mushroom Walnut Vegan Taco Meat (Gluten-Free)

This easy and flavor-packed Mushroom Walnut Vegan Taco Meat will cook up in about 15 minutes of your time and requires simple ingredients that you might already have on hand! Plus, it is both vegan and gluten-free!

8.3. 1.Preparation

20 minutes soaked walnuts are drained and set aside. With 2-3 tablespoons of water onions and garlic are cooked in nonstick pan over medium heat. Walnuts and mushrooms are pulse in a food processor until they have broken down into a “meat crumble”-like texture. Transferred to the pan along with the cumin, chili powder, tomato paste, soy sauce, oregano, liquid smoke, and 1/4 cup of water. The mixture is cooked for 8 minutes, or until it beings to brown and the mushrooms soften. Eliminate the heat and season with salt and pepper as desired. Mix through the cilantro plus lime juice to taste.

9. RESEARCH ON PLANT BASED MEAT ALTERNATIVES

The topic of plant-based meat alternatives (PBMAs) has been discussed for several decades, but it has only recently become one of the hottest topics in the food and research communities. With the purpose of investigating the current situation of scientific research on PBMA and determining future research opportunities, the driving forces for PBMA development, a brief history of its progression, key technologies required for production, and the resulting consumer attitudes are summarized. Environmental, human health, and animal welfare concerns are the main factors that have driven the development of PBMA. Although its history can trace back to ancient Asian civilizations, the first generation of PBMA originated in 1960s and a new generation of PBMA designed for carnivore was developed in recently years. The recent developments in this field also include other protein sources, for example, microalgae proteins extracted from Spirulina (Percival, 2019) and proteins isolated from insects (Megido et al., 2016). Proteins synthesized *in vitro* (Zhang et al., 2020) and mycoproteins produced by fungal fermentation (Finnigan et al., 2019) have the advantage of forming elongated fibers Structuring methods such as extrusion and shear cell techniques have been widely studied, but improvements toward the overall appearance and flavor, biological and chemical safety control, as well as the selection of protein sources are also very important for PBMA production. The consumer acceptance of PBMA remains unsatisfactory but is continually improving. Based on those knowledge, future research opportunities include developing more effective strategies for consumer education, providing more scientific evidence for the health properties of PBMA, finding more suitable protein sources to improve the quality of the final products, improving the appearance and flavor, further examining and securing the chemical safety, exploring the structure formation mechanism during the extraction or shearing processes, and developing methods and standards for a quality evaluation of PBMA. Plant-based meat alternative (PBMA) has become one of the hottest topics in the academic community, and thus original research articles and review papers outlining different emphasis on this topic have been published. For example, Dekkers, Boom, et al. (2018) and Kumar (2016) summarized the key technological developments for plant-based meat analogues, with a focus on the structuring processes. Hu, Otis, and McCarthy (2019) and Smetana, Mathys, Knoch, and Heinz (2015) used life cycle impact assessment techniques to evaluate the sustainability of plant-based meat products. The health benefits (Neacsu, McBey, & Johnstone, 2017; Sadler, 2004) and the consumer perceptions (Bryant, Szejda, Deshpande, Parekh, & Tse, 2019; Slade, 2018; Wild et al., 2014) of PBMA have also been surveyed and reviewed. However, it is believed that an inclusive review on PBMA is currently lacking in published literature. With the purpose of providing the general picture of the current situation of scientific research on PBMA and therefore identifying the gaps to determine future research opportunity, related scientific literatures that published in the past two decades were searched in Agricola databases and CAB databases. The literatures were then summarized into four aspects, that is, the driving forces for PBMA development, its history, manufacturing, and consumer attitudes toward PBMA. Our perceptions on each aspect were then provided along with our general opinions on this topic.

10.1 HISTORY OF Plant Based Meat Alternatives

The consumption of processed plant-based protein products can trace back to the ancient civilizations in countries such as China and India. Plant-based protein products such as *tofu*

(Shurtleff & Aoyagi, 2013), *tempeh* (Babu, Bhakyaraj, & Vidhyalakshmi, 2009), and *seitan* (Day,

2011) have been documented in these countries since ancient times. These types of traditional plantbased products are typically used as a protein alternative in Buddhist and vegetarian dishes. With the increasing number of vegetarians (Leahy et al., 2010), particularly in developed countries, further plant-alternative products have been developed. During the 1960s, textured vegetable protein (TVP) was invented and the concept of PBMA was further advanced as

TVP was used as the main ingredient for plant based versions of meat-based dishes, such as burgers and bacon (Riaz, 2011; Riaz, 2001). In recent years, corporations such as Impossible Foods and Beyond Meat have developed a new generation of PBMA to satisfy meat eaters. The newest versions of PBMA have similar structures, comparable smells, and even a bloody appearance to help mimic animal meat, which has proven to be popular among consumers. The increased importance of meat analogue in the current trend is due to the health awareness among consumers in their diet and for a better future environment. The factors which lead to this shift is due to low fat and calorie foods intake, flexitarians, animal disease, natural resources depletion, and to reduce greenhouse gas emission. Currently, available marketed meat analogue products are plant-based meat in which the quality (i.e., texture and taste) are similar to the conventional meat. The ingredients used are mainly soy proteins with novel ingredients added, such as mycoprotein and soy leghaemoglobin. However, plant-based meat is sold primarily in Western countries. Asian countries also will become a potential market in the near future due to growing interest in this product. Labgrown meat with no livestock raising or known as cultured meat will be expected to boost the food market in the future, with the current advance technology. Also, insect-based products will be promising to be the next protein resource for human food. Nevertheless, other than acceptability, cost-effective, reliable production, and consistent quality towards those products, product safety is the top priority (Ismail, I et al., 2020).

The ‘new meat alternatives market’ promises a healthy, ethical, and sustainable product that is made from plant ingredients and fabricated to replicate meat. With an increasing societal awareness for the ethical, environmental, and individual health impacts of eating animals, more and more consumers decide to either cut down or avoid the consumption of meat and on other animal products altogether (Mintel, 2017). Also, with that new market, there are new products, new companies, and large investments into meat-free meats

(The Economist, 2015). In contrast to the rather recent mainstream business expectations and investments, British consumers have been able to buy a diverse range of meat alternatives in most major supermarkets for over two decades, and for many decades prior outside of the mainstream market.

Most accounts of the history of meat alternatives start with soybeans in ancient China, where the highly proteinaceous crop has been used and cultivated for over three millennia; according to Shurtleff and Aoyagi (2014), tofu (coagulated soy protein) was first mentioned in a document from 965 CE, in which the consumption of tofu as an alternative to meat is advocated. Cooked wheat gluten (today known as seitan) has also been used in China for many centuries; the creation of fibrous, meat-like foods from it was first mentioned in 1301. Another 'traditional' meat alternative available today is tempeh (fermented soybean cake) which is likely to exist since the early 1600s, in Java, Indonesia (Shurtleff & Aoyagi, 2011, 2014, p. 5). In ancient China, plant-based meat-like products were especially popular in the country's Buddhist periods, as meat was then forbidden for religious reasons (Shurtleff & Aoyagi, 2014).

The first references to replacing meat in the UK originate in Victorian England, when a vegetarian community of considerable size emerged. Vegetarian advocates promoted a purist diet based on wholesomeness, taste, price, and simplicity. However, it was also recognised that popularisation of the diet required more appealing foods, hence it was not uncommon to create cutlets, sirloins, etc. from vegetables (Gregory, 2007, p. 129). Vegetarian recipe books featured alternatives to meat dishes such as sausages, steaks, or cutlets. Towards the end of the 19th century, people called for more diversity in the vegetarian diet and replacements for animal ingredients. In consequence, a large variety of nut meats and other protein-rich products were created and sold (Gregory, 2007).

10.2 The Safety Control of Meat Substitutes

Rapid global population growth has caused an increasing need for products containing protein. Meat products are the most familiar high-protein food source, but impact the environment, cause animal welfare issues, and raises public health concerns. Consumer health and food safety are paramount to the food industry. Both the scientists and food industry are actively seeking plant proteins to substitute for animal-sourced proteins. Plant proteins have a well-balanced amino acid composition, and exhibit great potential for replacing meat via the development of healthy, highprotein, lowsaturated fat, cholesterol-free, and nutritionally similar meat-like products Sun, C et .al (2020).Like in every other food product, food safety is an essential aspect for PBMA production. Although the microbial and chemical safety of meat products has been well researched, there is limited scientific data related to the safety of PBMA. Unfortunately, PBMAs have a higher risk of microbial growth and reproduction as they provide high-moisture environments with a neutral pH. In a European research project ("LikeMeat"), the microbial control of PBMA was studied, and it was determined that when the extrusion products were exposed to high temperatures, both the lab- and pilot-scale procedures demonstrated similar results in the bacteriocidal and sporicidal effects (Wild et al., 2014). The results showed that on average there were less than 100 colony forming units per gram of extruded product (Wild et al., 2014); however, further contamination could be introduced through the surrounding environment or even through the addition of nonsterile food ingredients after the extrusion process (Sagoo et al., 2009).

Consequently, the study of the microbial quantification in PBMA products led to the conclusion that post extrusion thermal treatments must be carried out to elongate the commercial shelf life (Wild et al., 2014). When further sterilization was applied to intermediate and final meat alternatives, a significant reduction in microbial activity was observed when stored at 6 °C for prolonged periods (Wild et al., 2014). In summary, the expiry date of intermediate goods from the "LikeMeat" project that have not undergone further treatments with heat and preservatives is similar to that of consumable meat (Wild et al., 2014). Therefore, it is highly recommended that the system for the storage and handling of PBMA remains similar to that of raw meat (Wild et al., 2014).

As the world's population increases, the need for reliable protein products is growing. Meat is considered a good source of high biological value protein, but meat is not sustainable. In Western countries, the shift toward a diet with reduced meat consumption demands healthy and tasteful meatfree food products. Following this trend, the market turned toward vegetable proteins, such as pulses, wheat gluten and soy protein, which are processed into meat-like products, also known as meat analogues. These products approximate certain aesthetic qualities, such as texture, flavour, and colour, and nutritional characteristics of specific types of meat. The development of new, attractive food products is a challenge already, but this challenge becomes even greater considering that these products are meant as a substitute for meat (Kyriakopoulou, K et al.,2018).

It is important to ensure the chemical safety of meat goods for consumers. Process-induced hazard chemicals, such as PAHs (Ledesma et al., 2016; Nisha et al., 2015), *N*-nitrosamines (Cantwell & Elliott, 2017; Herrmann et al., 2015), and HAAs (ur Rahman et al., 2014; Raza et al., 2015), have been detected in various meat products. Because to the presence of these harmful chemicals in processed meat, these products have been labelled as Group 1 by the IARC as they are carcinogenic to humans. In many food products such as smoked and grilled meats, PAHs can arise through the combustion of organic material or through the partial combustion of charcoal (Andrée, Jira, Schwind, Wagner, & Schwägele, 2010; Engel, Ratel, Bouhlel, Planche, & Meurillon, 2015). *N*nitrosamines are mainly formed by reactions between nitrogen oxide and amines, for example, the cooking of pork meat brings about the formation of *N*-nitroso proline (Andrée et al., 2010; Engel et al., 2015). HAAs include more than 20 compounds and are classified as aminoimidazoazaarenes and carbolines. The former is produced through Maillard reactions that are activated through cooking temperatures of approximately 150 to 200 °C, whereas the latter forms at temperatures greater than 250 °C when radical reactions begin to take place (Andrée et al., 2010; Engel et al., 2015). Based on how these toxicants are formed, it is believed that meat subsitutes products may also possess these compounds; however, scientific literature lacks sufficient data to come to a conclusion. Recently, our group has carried out the screening and detection of toxic compounds, such as *N*-nitrosamines and PAHs, in commercially available PBMA. Despite the fact that most of the targets were undetectable in all samples cooked under recommended conditions, *N*nitrosodiethylamine was detected in one cooked sample at a concentration of 15.19 ± 1.21 μg/kg (data unpublished). Other contaminants, such as heavy metals and pesticides that originate from ingredients or the surrounding environment, have not been tested. Thus, additional research must be carried out to further evaluate the chemical food safety of PBMA, and the control measures for these chemical contaminants must be explored. In general, the use of high-quality ingredients for PBMA production and cooking with the appropriate time and temperature would serve as effective strategies; however, supplementary scientific data are needed to support these assumptions. In addition, the safety evaluation of certain special ingredients used in PBMA is also imperative. For instance, the safety of *Pichia pastoris*-expressed soy leghaemoglobin protein, which was used as a flavour catalyst for PBMA, was previously evaluated by Fraser, Shitut, Agrawal, Mendes, and Klapholz (2018) and no toxicological concern was raised.

Plant-based substitutes and cell-based meats are gaining a foothold in global markets. This review of the evidence explores the extent to which the production and consumption of meat alternatives can mitigate some of the environmental, animal welfare, and public health problems associated with farmed meats, per how these products are often promoted. In doing so, we highlight the complexity of the issues at hand and the need for cautionary approaches to the rapid adoption of these products.

From an environmental perspective, plant-based substitutes can provide substantial benefits over farmed beef, to which they are most often compared by industry and media. Cell-based meat could provide benefits as well for most environmental concerns, with a few caveats: the GHG footprint, blue water footprint, and industrial energy use could be higher than those of farmed beef in some cases. Compared to farmed pork, poultry, eggs, and some types of seafood, the environmental benefits of meat alternatives are generally less pronounced (in the case of plant-based substitutes) or potentially non-existent (in the case of cell-based meat), a nuance that should be more transparent in discussions around meat alternatives.

From an animal welfare perspective, if meat alternatives replace even a small share of farmed meat production, this could substantially reduce the number of animals raised and killed for human protein consumption, demonstrating the ethical appeal of these products. Cell-based meat will, however, require further technological developments to remove all animal-based inputs including fetal bovine serum.

From a public health perspective, there has been limited research on nutrition, chronic disease, and food safety implications associated with consuming meat alternatives, and occupational and community health implications associated with their production. For example, it is unknown whether replacing farmed meat with plant-based substitutes would offer similar nutritional and health benefits as less-processed plant foods; the relative benefits would depend on the extent to which plant-based substitutes are replacing red and processed meat. Meanwhile, many of the purported health benefits of cell-based meat are largely speculative at this time, given the level of uncertainty around macro- and micronutrient content, the scope and nature of antibiotic use, and waste management practices.

The broader socioeconomic and political implications of widescale replacement of farmed meat with meat alternatives are also critical to consider, despite their frequent omission from most existing research. Meat alternatives are not intended to address concerns associated with industry consolidation, or the loss of farmers' and public autonomy over the food system, but as products to be offered within existing protein supply chains that appeal to those who enjoy meat but seek to reduce environmental, animal welfare, and public health harms. That said, these products illuminate important economic and political tensions between livestock producers and processing/marketing companies, between the workers who may benefit and those who may lose opportunities from their rise in popularity, and between consumers who may or may not be able to access them.

There is no silver bullet solution to addressing the myriad public health, environmental, and animal welfare challenges associated with protein consumption. While plant-based substitutes and cellbased meats may offer many benefits over some farmed meats, it is critical to remain cautious and nuanced in discussing their merits rather than assuming that they will solve our current challenges without any drawbacks. By the same token, these products should not be dismissed out of hand as fringe developments in the food system or as simply "imitations," but should be approached with the same nuance as other foods. At the same time, the role of shifting toward more diverse, unprocessed whole foods (including pulses) while providing economic support for more agroecological producers—more than just substituting processed foods within otherwise unhealthy dietary patterns and inequitable supply chains—should not be overlooked. Mitigating the systemic problems of our food system will likely require the food processing and service industries, producers, and consumers to think beyond simply replacing one "meat" on a plate with another.

11. Functions and sources of Vegan Meat

The main function of vegan meat is to replace meat in the diet . The market of vegan meat does not only includes vegetarians but also the Semi-Vegetarian, Pesco-Vegetarian and Omnivorous Diet seeking to reduce their meat consumption for health or ethical reasons, and for people following religious dietary laws, such as Kashrut, Halal, Buddhist and many more . Some meat analogues are basically made with the centuries-old recipes for wheat gluten, rice, mushrooms, legumes, tempeh, or pressed-tofu (Table 1), with some flavouring added so that the finished product tastes like lamb,ham , chicken, beef, sausage, etc (Kumar,2016).They can be used to reduce cost expression because they are cheaper than meat. Some other attributes such as freezing , reheating, the ability of retaining water and moisture during cooking and thawing makes them highly appreciable. Texturized vegetable proteins (TVP) such as soye protein, pea protein , mushrooms are commonly used to provide the desired amount of chewiness ,quality, texture, binding ability , or to make a product firmer or softer (Riaz, 2005). Vegan meat have a good number of health benefits too as mentioned above in section 5. Vegan meat consumption over the meat provides many health benefits such as protection against heart disease, lower blood cholesterol, reducing the risk of cancer and increasing bone mass (Sadler, 2004). Food scientists by studding the present situation are now creating meat alternatives that truly taste like meat and have the same "mouth feel" their naturemade counterparts.

Table 1: Major nonmeat protein sources suitable for Vegan meat.

Types of protein	Sources	References
β-conglycinin	Soybean	Sun et al. (2008)
Glycinin, Vicilin	Legumes	Kang et al. (2007)
Legumin, Albumins, Globulins Glutelins	Oil seeds	Marcone (1999)
Gluten Gliadins Glutenins	Wheat, rye and barley	Green and Cellier (2007)
Mycoprotein	Fusarium venenatum (Filamentous fungus)	Denny et al. (2008)

All this innovation in this field could be great news for all those people who are concerned about the health problems related to over consumption of fat, salt and cholesterol. There is also a need to look for new ways to raise nutrition for the poor at a minimum cost. Fortunately, there are thousands of plant proteins all around the world, and many of them have yet not been explored for use in the production of meat alternatives. Current investigations of the world’s vast array of plant proteins can fundamentally reshape our food supply for the better. The researchers are hopeful that they would be able to meet the demand for a protein-rich diet in a new way. All these aspects have briefly been reviewed in this paper (Kumar,2016).

Economic aspects and future trends

An important reason for the increased acceptance of plant protein is their low cost and texture. The major challenging task for the food engineers however is to develop the three dimensional structure from these plant proteins while maintaining their nutritional properties so as to provide these alternate meat products the same meaty texture. Texturized wheat gluten is commercially available in several forms differing in size, shape, density, color, and texture. The popularity of texturized wheat gluten is rapidly increasing due to abundant production of wheat throughout the globe. The researchers are trying to develop wheat varieties that have a minimum amount of gluten while maintaining its technological properties. Genetic engineering can enhance the quality of plant based food products through the silencing of genes. New plant based meat anlogues should taste, feel and smell better, or at least as good as animal meat according to the perceptions of the majority of consumers. It is very probable that (umami associated with meat) and texture (like as in meat products) are the most important keys to success, and at the same time, the biggest challenges for the researchers.It can be concluded that there is a demand as well as bright future of such products in the market keeping aside a few constrains which need solution but with a the heap of opportunities.

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Web links

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