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Plant based meat analogue: a review

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

1. 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).

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

(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.

2. 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.

2.1 Techniques 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 plant-based 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.

2.2 The most important ingredient of meat analogues and traditional meat products

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)

3. 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). Besides, 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. Health benefits of vegan meat

Vegan meat contain high amounts of dietary fibre, n-6 fatty acids, vitamins C, B9 and E, for magnesium, potassium, carotenoids, plant sterols and many other phychemicals, which are commonly associated with numerous health benefits. The wide range of antioxidants in a plant-based diet prevents oxidative stress that plays an important role in carcinogenesis and development of endothelial dysfunction, and in the initial steps of pathogenesis in atherosclerosis (Chauveau et al., 2013).Vegan diet implies lower intake of saturated fatty acids, cholesterol, calcium, vitamin B12 and D, as well as a higher in-take of dietary fibre (Fields et al., 2016).To date, a large body of evidence has shown that a vegetarian diet is associated with significant-ly lower prevalence of overweight and obesity, as well as with a lower risk of cardiovascular hospital admission and 32% less mortality. As concluded by Crowe et al. (2013), even after accounting for body mass index, vegetarians remain 28% less likely to develop ischemic heart disease. A recent meta-analysis (Yokoyama et al., 2014) examining the relation-ship between vegetarian diet and blood pressure has shown that a diet excluding meat, but involving regular consumption of dairy products, eggs and fish was associated with 4.8–
6.9 mm Hg lower systol-ic blood pressure, compared to an omnivorous diet. The estimated reduction in blood pressure was as-sociated with 9% decreased risk of death from coronary heart disease and can be equated to the health benefits of a 5 kg weight reduction or a low- sodium diet.In addition to this, the vast number of studies that have explored the link between plant-based di-ets and malignant diseases reported the overall risk of cancer is somewhat lower in vegetarians com-pared to omnivores. However, when it comes to the location and type of cancer that can be prevented by plant-based diets, findings are rather scarce and inconclusive (Key, 2017). The prospective cohort study of Bradbury et al. (2014) aimed at exploring the associations between fruit, vegetable and/or fi-bre intake and cancer risk and included more than 500,000 participants from 10 European countries. According to the results, the risk of gastrointestinal tract cancer and liver cancer was inversely as-sociated with excessive consumption of plant-based food, as well as for stomach, cervix, biliary tract, pancreas, prostate, kidney, endometrium and bladder cancer, no significant asso-ciation was reported between incidence and total in-take of vegan meat. Similarly, Gilsing et al. (2016)

reported that after accounting for con-founding factors, vegetarians, pescovegetarians and 1 day- per-week meat- eater did not have a reduced risk of postmenopausal breast, lung or prostate can-cer compared to those consuming meat on a daily basis. The largest body of epidemiological data relates to the risk of colorectal cancer and excessive consumption of red and processed meat (Chauveau et al., 2013), but the results also turned out to be divergent (Boskovic and Baltic, 2016). A recent study (Michelle et al., 2015) with 77,659 partic ipants showed that vegetarians have a 22% low-er risk of developing all colorectal cancers com-pared to non-vegetarians with a similar background. Furthermore, the authors emphasised that eating a pescovegetarian diet was associated with the low-est risk of colorectal cancer (a 43% risk reduction compared with omnivores), while the risk of colo- rectal cancer in semivegetarians (risk reduction of 8%) was closest to the risk that meat consum-ers face (Michelle et al., 2015). A similar conclusion was reported in a meta-analysis and systematic review of prospective cohort studies by Godos et al. (2017). According to their findings, the risk of colorectal cancer was lower in the population that consumed a semivegetarian diet (relative risk 0.86) and pescovegetarian diet (relative risk 0.67) when compared to non-vegetarians (Godos et al., 2017). However, in contrast to this, Koushik et al. (2007) followed 756,217 men and women for 6 to 20 years and showed that excessive intake of fruit and vege-tables was not strongly associated with colon cancer risk reduction.The controversial findings in the current lit-erature are driven by the fact that studies exploring the relationships between diet and health face two main challenges. First, it is difficult to discriminate the specific effects of vegetarian diets from thosthose lifestyle factors that are often associated with veg-etarianism, such as lighter body mass index, high-er levels of physical activity, and lower prevalenc-es of smoking and alcohol consumption. In addition to this, it remains unclear whether the established health benefits of vegetarian diets can be attribut-ed to the avoidance of red meat, avoidance of pro-cessed meat, limited intake of saturated fatty acids and cholesterol, increased intake of fruit, legumes, vegetables, grains nuts, and soya protein-foods, or to all or combinations of these.

5. Health hazards associated with mock meat

while higher intake of plant foods and mod-erate amounts of saturated fatty acids, cholester- ol and processed meat can be considered beneficial for health, the existing evidence from cohort stud-ies suggests that the complete elimination of animal foods might not be associated with additional bene-fits for human health (Godos et al., 2017). Meat is a source of biologically valuable proteins, long chain n-3 fatty acids, essential trace elements (iron, cop-per, manganese, iodine, zinc, selenium), vitamin D and several B vitamins (Baltic et al., 2010; Ivanovic et al., 2016; De Smet and Vossen, 2016). Therefore, the potential drawbacks of vegetarian diets mostly refer to the reduced supply of essential amino acids, n-3 fatty acids, vitamin B12, zinc, iron and calcium (Petti et al., 2017).Vegetarian diets are abundant in n-6 fatty acids (linoleic acid), while lower serum levels of n-3 fat-ty acids, i.e. eicosapentaenoic acid (EPA) and doc-osahexaenoic acid (DHA), which are thought to be important for immune, cognitive and cardiac func-tions, have been reported in vegans (Pavlicevic et al., 2014). Plant-derived linolenic acid can be con-verted to EPA and DHA in vivo, but the conversion rate is rather slow and vegan sources of n-3 fatty ac-ids are limited to canola oil, flaxseed and flaxseed oil, and olive oil (McEvoy et al., 2012).Iron deficiency is a cause of anaemia in ap- proximately 30% of the population in wealthy coun-tries, particularly in urban residents and young fe-males. The vegan population exhibits an even higher tendency for anaemia not because their iron intake is below recommended levels, but because non-hae-me iron from plants is less bioavailable and because plant-abundant diets contain substances such as phytic acid and polyphenols/tannin, which can im-pair mineral absorption. A vast number of studies aimed at exploring vegan health with respect to vitamin B12 deficiency, since B12 requirements cannot be met without animal-based food intake or supplementation, and in affected people, B12 deficiency and the accompanying haematological symptoms can be mimicked by folic acid intake, which is high in vegan diets (Baltic et al., 2010; McEvoy et al., 2012).Although plasma levels of vitamin B12 are lower in the en-tire vegetarian population than in meat-eaters, cas- es of pronounced vitamin B12 deficiency with sub-sequent haematological and neurological damage, such as central nervous system demyelination, have been reported only in vegans (Kapoor et al., 2017). This is because followers of less strict vegetarian diets, such as ovolactovegetarians, lactovegetarians and semi vegetarians, obtain B12 through consumption of cheese, eggs, milk, and artificially fortified products. Apart from haematological and neurological effects, vitamin B12 deficiency is shown to be associated with atherosclerosis. As reported by Woo et al. (2014), low intake of meat, egg or dairy prod-ucts in poor residents of northern Chinese rural communities and consequent vitamin B12 deficiency have been associated with impaired arterial endothelial function and increased thickness of carotid inti-ma- media. In addition to vitamin B12 deficiency, plant-eaters who avoid animal-based protein might be lacking several key nutrients, including sulphur amino acids, iron, zinc and omega-3 fatty acids, which can be associated with the elevated blood levels of homocysteine and decreased high-density lipoprotein levels often reported in vegans (In gen bleek and McCully, 2012). In order to meet the daily requirements and decrease vulnerability to atherosclerosis, vegans should be encouraged to take vitamin B12 supplements and consume walnuts as a source of n-3 fatty acids (Li, 2011).The relationship between vegetarian diets and skeletal integrity was a matter of scientific debate due to the fact that it is challenging to distinguish be-tween the effects of diet and certain lifestyle factors (e.g. physical activity, smoking and caffeine intake) on bone health. The EPIC-Oxford study (European Prospective Investigation into Cancer and Nutrition – University in Oxford) performed between 1993 and 1999 showed veganism poses a risk of calcium and vitamin D deficiency, particularly for people living in northern latitudes with low sunlight exposure (Crowe et al., 2011). Nevertheless, more recent findings have shown the daily average vitamin D intake of vegan has increased noticeably by almost 12-fold in the last 20 years due

to newer dairy replace-ment products that are typically fortified (Dagbasi et al., 2015). Moreover, the lower bone density in people consuming plant-based diets was confirmed, but it cannot be considered as clinically relevant as no significant differences in osteoporotic fracture rates between vegetarians and non-vegetarians were registered.

6. 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 .

6.1. Impossible meat-

6.1.1. 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

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

6.2.1. 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 .

6.3. 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!

6.3. 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.

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.

7.1 HISTORY OF Plant Based Meat Alternative

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. Lab-grown 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).

7.2 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 meat-free 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.

7. 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).

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