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Plant-Based Meat for Future Food Security of Growing Population and Environmental Sustainability

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ABSTRACT

Animal products are typically the main sources of human intake because proteins are vital components of human nutrition. However, a large increase in vegetarian and vegan dieters has brought attention to the need for substitutes for animal proteins, i.e meat analogues. The term "meat analogue" refers to the substitution of another component for meat as the primary ingredient. It is also known as a meat alternative, meat substitute, mock meat, and imitation meat. Concerns about the environment, human health, and animal welfare are what primarily motivated the invention of Plant based meat alternatives. This review compares the production and consumption of plant-based meat alternatives to that of farmed meat in order to identify the important public health, environmental, animal welfare, economic, and regulatory implications.

The current trend's rising significance of meat alternatives is brought about by customers' heightened dietary health consciousness and concern for the environment. The use of low-fat and low-calorie meals, flexitarians, animal sickness, the loss of natural resources, and efforts to minimize greenhouse gas emissions are the factors that have contributed to this transition. The meat substitutes that are currently on the market have qualities (such as texture and flavour) that are comparable to those of traditional meat. The main component available in the market is soy protein, with novel components including mycoprotein and soy leghemoglobin added. But people who are suffering from soy protein allergies and disorder like hypothyroidism are not suitable for soy protein meat, so there is a need to develop meat alternative with the use of other nutritious veggies like pea, beet root, jack fruit etc.

1. INTRODUCTION

In the course of history, meat is an essential part of diet for human (Stanford and bunn 2001). The utilization of meat has been significant key for human evolution due to association with brain development and growth related to earliest *Homo sapience* (Williams and Hill, 2017). Universally, beef, pork and chicken products are upmost in demand and the United States and Australia come on the top regarding the highest annual meat consumption (Ritchie, 2019). As a result of rising population and fast economic development, the global demand of meat has been rose up to 58% in last two decades (Whitnall and Pitts, 2019). More or less 320 tonsof meat was used up globally by 2018 (Whitnall and

Pitts 2019), and it is prognosticated that the market will be open up to 15% by 2027 (OECD/FAO, 2018). Although, the less production of meat compared to crop harvesting and the adverse effects on human health regarding consumption of meat have become a topic of concern in the last few years (Godfray et. al. 2018, Marinova and Bogueva, 2019). As a result of these rising concern, food industries are trying to find ways to introduce meat alternatives, that made from animal free proteins, but must contain same appearances, mouth feel and smell to regular meat (Kumar et.al. 2017, Malav, Talukder, Gokulakrishnan and Chand, 2015). Nowadays the food research community is seeking for two main varieties of meat analogues, culture base meat (also known clean meat, in vitro meat), (Bhat &Fayaz, 2011, Hocquette, 2016) and plant- based meat. Plant based meat is produced by extracted protein obtained from plants by the proper structuring processes some other meat alternatives (Quorn ™ Products) (Peregrin, 2002, Wiebe, 2004) and insect-based meat analog products, as well as insect- based burger from Coop (Swiss food retailer) and insect fortified burger from Bug foundation (Germany food company)(Ismail, Hwang and Joo 2022), have also been marketed over the last few years.

Tissue engineering technique is used to produce culture-based meat (Bhat and Bhat 2011, Noor, Radhakrishnan and Hussain 2016). Presently, artificial hamburger has been produced in laboratory by using in vitro technique, is a confirmation that notion can be used to the food industries (Dekkers, Boom and Van Der Goot, 2018). However, burgers & sausages, processed fungal based meat are accessible in the market for decades, but the production exercise is relatively complicated and needs high amount of energy (Dekkers, Boom et. al. 2018). Whereas,insect- based meat alternative is not much acceptable by consumers that leads the hurdle for its development. Taking into consideration, the long utilization of traditional processed plant- based food as protein (tofu & tempeh) in Asia, plant- based meat has the capability to rise up as a popular product among all commercial meat substitutes. Even, the public media has mentioned that 2019 has been the year of plant- based burger due to its development of several plant- based meat brands in recent years. Such as, beyond meat™. Impossible food ™, and Light life ™.

In the academic society, plant- based meat alternative has become one of the topic for discussion, and thus research articles and review papers touching on different area on this topic have been published. Such as, Dekkers, Boom, et.al. (2018) and Kumar (2016), sum up the key technological developments for plant -based meat analoque, with a center on the structuring procedure. Hu, Otis and Mc Carthy (2019) and Smetana, Mathys, Knoch, and Heinz (2015) work on life cycle impact assessment techniques to examine the sustainability of plant- based meat products. The beneficial effect on health (Neacsu, McBey and Johnstone, 2017, Sadler, 2004) and the consumer view point (Bryant, Szejda, Deshpande, Parekh, &Tse, 2019, Slade, 2018, Wild et. al. 2014) of plant- based meat analogue have been also observed and reviewed. However, it is be of the opinion that a comprehensive review on plant-based meat analogue is still lacking in published literature. With the sense of purpose for presenting the general picture of the current state of affaire of scientific research on plant -based meat analogue and consequently pin-pointing the gaps to determine further research opportunity, associated scientific literatures that published in the last two decades were searched in Agricola database and CAB database. After that the literature were summarized into four points that are; the driving forces of plant-based meat analogue, development, history, manufacturing and consumer's frame of mind toward plant-based meat analogue.

2. HISTORY

Ancient time: The idea of the substitute of meat as a protein source occurred from ancient time, containing traditional products i.e. tofu, tempeh, and Seitan, a standard meat analog, was grown or evolved in China by the Han dynasty (206 BC- 220 AC). Out of them the tofu was broadly consumed all over the Tang dynasty (618-907) and possibly reached out to Japan during the later Tang or early Sang dynasty (Shurtleff & Aoyagi 2013).

Early 20thperiod : Nut and Cereal- based products arose in the early twentieth century, such as Nuttose and Protose, produced by pioneers like John Harvey Kellogg, to encourage good health (Shurtleff & Aoyagi, 2014). In addition, apart from traditional Asian products, the concept of dry texturized vegetable

protein was also developed, which was come by extruded defatted soy meal, Soy protein concentrates, or wheat gluten (King and Lawrence 2019)

Mid to late 20thperiod :- Mid to late 20th period, tangible sign of development were established in the production and packaging industry, which put on noteworthy development in plant protein concentrates, isolates, and texture proteins. These developmentsencouraged the synthesis of Soy-based meat alternatives all over the time when meat consumption was surging in various industrial nation by agricultural expansions and strengthened animal farming. Focused at a niche of vegetarian demographic products like Tofurky arose in the US in 1980 (Pullen 2018)

Early 21stPeriod: The first American meat alternative is Burger king that penetrated the good chain in 2002 as a traditional plant-based burger. In the new millennium, sensibility related to well-being and sustainability sign of user's diet sustained to increase together with the arising demand for alternative to regular meat (Green, 2019). The new age of products like Impossible Burger and Byeon Burger has produced a new generation of analogs, which resulted the plant-based meat industry to be doubled. Enhanced by present time development in food science and manufacturing, plant-based meat aims to pretend the taste, texture, appearance and functionally of traditional sausages, burgers, and fillets. Moreover, meat alternatives, produced from fusion of plant- protein, fat, gums, spices and extrudes processing technologies have attained or reached robust consumer acceptability globally (court E, 2018)

Nutritional values and composition

While growing the plant-based meat alternatives, the weightage is given to design a product with similar organoleptic characteristics as meat and matching the nutritional significances of focused/ aimed meat product (Kyriakopoulou et.al. 2019). By the whole of the macronutrient, the key focus is concentrated to protein percentage. In addition, to maintain the parallel functional and nutritional properties as of the meat products, moisture and lipid levels of the meat analog are also regulated. Thus, it can be mentioned that the meat analogs are perfectly equivalent to the traditional meat products in the matter of nutritional value especially the macronutrients.

Presently, beef burger simulation products think about the most famous and accepted meat substitutes. Various food services and retail products come under this category. While describing the characters the nutritional value of beef products. McDonald's beef patty and cooked ground beef (lean = 93%, fat = 70%) are thought to be the standard meat products. As reported by the USDA Nutrient database (USDA, U.S. Department of Agriculture, 2019), ground beef contains a caloric value of 182 kcal/100g with 25.56% total protein content, 8.01% total fat, 3.29% saturated fat, 0.084% cholesterol, 0.072% sodium and 0.0028% iron with carbohydrates and dietary fiber. In addition, the nutrient significations of McDonald's beef patty contain 23.33% protein content, 20% total fat percentage, 8.33% saturated fat, 0.083% cholesterol, 0.4% sodium and dietary fiber and having a total caloric value of 266.67 kcal/100g.

Anderson et.al. (2009) examined meat alternatives that simulate beef burger products and set up parallel nutritional profile as of the meat i.e.McDonald beef patty. The two products particularly, Beyond burger and Impossible burger were found matching with the McDonald beef patty in the matter of total fat content i. e. 5.31% and 7.08% as against to 8.33% in meat. In one more formulation, two separate meat ball products were matched with a meat analog (Gardian meatless meat ball). The nutritional evaluation opened up that the meat analog had a parallel protein content of 15.56%. although, a lower energy value (166.67% kcal/100g versus 16.47/100g) saturated fat (0.56g/100g versus 5.88g/100g) and cholesterol level (0.00mg/100g versus 47.06mg/100g) was noted.

Environmental and health impact:

3. ENVIRONMENTAL CONCERNS

Livestock production accounts that human activities are responsible up to 14.5% global green house green gas (GHG) emission (Gerber et.al. 2013). Dairy and meat from ruminant animals (e.g. cattle, goats), farmed crustaceans (e.g. shrimp, prawns), and trawled lobster are remarkably GHG- intensive (Clune et. al. 2017, Poore and Nemecek, 2018, Kim et.al. 2019). Some studies indicate that soil, climate and animal density that comes under the specific conditions, well-control grazing livestock may bind up carbon, thus decreasing the GHG level of ruminant products (Tichenor et.al., 2017); however other study indicates that these effects are limited in term of time, reversible, and probably

outweighed by other GHG's produced by grazing systems (Garnett et.al. 2017).

The approximated amounts of livestock mass production related to land ranges from 2.5 (Mottee et.al. 20170 to 3.7 billion ha (Foley et.al. 2011) nearly half to three quarters of universal agricultural land – whereas animal foods accounts for hardly 18% of calories and 25% of protein in the universal food supply (Mottet et.al. 2017) this is because of the amount of forage and feed need to generate an equal amount calories and protein from meat as could be supplied directly from plant grown for earthling consumption, with the caveat that animal proteins basically are much bioavailable to earthling and have each and every basic amino acid in adequate amounts (Cassidy et.al. 2013). Beef is incredibly land- intensive related to other meats (Poore and Nemecek, 2018) in past due to cattle shows a moderate reproductive period and are not much efficient at transforming feed to meat (Nijdam et.al. 2012).

Despite the relatively huge area footmarks of farmed animals, there are two major and associated concern in regarding to the contributions of grazing ruminants to land requirement and protein security/surety. Foremost, as opposed to pork, poultry and progressively farmed fish (Fry et.al. 2016) which are dependent on crops for their feeding that grown on land that could be used for growing crops and can utilize for direct human consumption and ruminant animals can use unsuitable land for grazing e.g. too rocky or too hilly. Of the 2.5 billion ha spared to livestock constructions, 1.3 billion ha are non-arable grasslands (Mottet et.al. 2017). Hence, less beef mass production and utilization would not surely free up a proportional amount of land to purpose of feed people and more livestock (Peters et.al. 2016). Secondly, farmed animal, especially grazing ruminant, can turn inedible plants into edible protein for human. In United Kingdom, grassland base system was observed to provide 1.1 kg protein from milk per kg of earthling- edible plant protein from forage and feed. In other hand, pork, poultry and grain-fed beef supply only 0.5, 0.4 and 0.3 kg protein sequentially, per kg earthling- edible protein of plant (Wikinson, 2011, Peyraud, and Peeters, 2016). Grassland production system introduce a possibility to contribute to protein security; grain-fed system, however stay the chief model of livestock production in industries dominant countries. For example, in the U.S. hardly 1% of the ongoing beef supply derive from exclusively pasture-based systems, however the potential exists to generate approximately 27-35% of ongoing beef supply playing with exclusively pasture (Hayek and Gassett, 2018). In general globally, ruminant meat presently depends on cropland to the similar range per unit of protein same as pork and poultry (Herrero et.al. 2015) Hardly any exceptions, more efforts for feed production (e.g. water, pesticides, fertilizers) are required to generate the same amounts of calories and protein in meat as to plant foods related for human consumption (Marlow et.al. 2009). Industrial livestock production also add up more to biodiversity loss (Machovina et.al. 2015) and disturbance in nutrient cycles that intensify groundwater pollution and eutrophication (Bouwman et.al. 2013) compared to crop production for earthling consumption. Eutrophication takes place if excessive nutrient levels (specially Nitrogen and Phosphorus)create toxic algae blooms that reduce oxygen levels in the water causing killing to fish, plants and other aquatic life. Resource inputs and the related impacts can be minimized with agroecological techniques like integrated crop livestock or multispecies farming, as well as nicely managed pasture- based livestock production system. These approaches can also allow more ecological service together with dependance on synthetic fertilizers by nutrient recycling, promoting soil health, and sustaining biodiversity by grassland system (Janzen, 2011, Roos et.al. 2017, Martin et.al. 2020).

4. FUTURE ASPECTS AND CONCLUSION

The popularity of cell- based meats is increasing in global market. The production and consumption of plant- based meats are helping in reducing several environmental, animal welfare and public health problems associated animal meat. Foremost, these plant- based meats helps in the reduction of global green- house gases. Other benefits include the reduction in killing of animals and reduction in the chronic diseases associated with animal meats including occupational and community health. However, several socio-economic issues and local problems and political implications need will have to be addressed in coming days. As there may be some problems with people associated in the business of livestock management and

processing/ marketing of the same. There is also a factor of adaptability or acceptability by a portion of people who are not used to change or new thing. However, with the Paris convention on climate change and recent problems of climate due to global warming, the prospects of plant- based meat are good and a source of future food.

Having said that, there is lot of scope in the research areas related to plant- based meat viz., working on economic source, looking for a source which can cover large population. Another aspect which can be looked is into the circular economy, i.e. using waste of some food product into animal meat. Moreover, there is lot of scope to work on the effective production of plant-based meat including suitable processing technologies, safety and quality control, shelf lives. Although the global acceptability of plant- based meat is not much at present but will surely increase with time and popularization. However, industries have to design proper strategies for consumer acceptance of these products.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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