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A review on meat analogue: Is this time to see the algal proteins as a sustainable substitute for the meat proteins?

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Abstract
Meat has been produced in huge quantity every year and the demand for the same is rising exponentially. Developed countries in the west consume meat as a primary source of protein and nutrients. However, East and Asian countries also prefer eating meat as a part of their meal but on the side. Meat production has been increased considerably in the last 5 decades as the demand rose. Unfortunately, due to the mass production of meat, various problems have also been increased such as global warming, freshwater shortage, large land usage, deforestation, extinction of species, new zoonotic diseases, waste production etc. It is also expected that the demand for meat will increase in the coming decade. Some people are aware of the harmful effects however, the large population is still unaware of the truth. Meat analogues are one of the solutions to tackle this problem by providing the population with meat like alternative to eat. Meat analogues are considerably more sustainable than the meat itself. These are produced using various ingredients from different sources. Proteins of meat analogue are obtained from different plants such as soybean and legumes. Algal proteins are a rich source of nutrients and amino acids. It has all the physicochemical properties that are required to be utilized in a food component. In this paper, an idea has been proposed in which algal proteins can be utilized as a source of protein in preparation of meat analogues. However, some challenges need to be overcome before utilizing it, such as pigment color, thermal stability and off flavor. Some technologies also have been discussed in the paper that may be used to overcome these challenges. Moreover, the production of algal proteins is a costly affair and hence not gaining much interest as a reliable source of protein to bridge the protein gap in the diet of people.

Keywords: Meat, meat analogue, algal protein, global warming

Introduction
Great apes were a taxonomic classification for animals such as chimpanzees, humans and gorillas. They were known for their intelligence and wide varied diet. They were describing as omnivores who can rely on fruits and nuts primarily. However, when these items were not available, they moved on to roots, shoots and even the flesh of other animals [1]. The flesh of an animal is termed meat. The meat was consumed since the beginning of the human era. Today, one can literally rely either on food obtained from animal sources or completely on plant-based food. However, apart from one's own will, the food eating habits and choice of food source depends on the culture, the person belongs to in some way or the other [2]. Western, European and eastern cultural analysis shows that there is a huge difference in eating habits when it comes to food like meat. In the western food culture, meat carries large importance and it is consumed as a major source of protein in their diet. The consumption of meat in the past decade has increased at the same rate as compared to other sources such as plant-based proteins which are somewhat stable [3, 4]. Meat is also considered a high-status food in western cultures, which makes it difficult to get substituted with any other food [5]. In European cultures, people like to consume other forms of meat also, apart from beef, such as pork and poultry meat [6]. However, in the eastern cultures, which itself is a diverse group of cultures with different eating habits and likings. Countries such as China followed by Korea and Japan are some of the largest consumers of meat in Asian countries [7]. Since 1961, global meat production has more than quadrupled. Asia was among the highest meat-producing continent with 15 folds increase in production capacity by 2013. Share of Europe and North America has reduced since 1961 in global meat production. However, the production capacity has increased by almost 2 folds and 2.5 folds respectively for both continents [8].

The consumption of animal products has significantly increased in the last 50 years [9]. Asia itself is a very big continent having various countries with different cultural and economic importance concerning the meat industry. China is at the top position in terms of population. The total meat production in the Chinese subcontinent was recorded as approximately 80,510,000 M/T from which pork meat was approximately 51,970,000 M/T [10]. In China, most prepared processed foods are from pork followed by other kinds of meat like beef, sheep, chicken, duck, fish, etc. however, pork is utilized mostly, all the parts of the animal are also fully utilized including other organs and skins. Eggs from ducks, hens and pigeons are also used in large numbers [11]. Korean cuisine is different from Chinese and Japanese cuisine with respect to flavors and colors. Here various flavors are usually put all together in all the meals. Korean cooking comprises grains and vegetables with spices with meat, fish or poultry on the side [12]. Pork has been an important part of Korean cuisine asan animal-based protein source since ancient times. Just like china, all the organs and parts of pigs are used in cooking using various cooking methods such as grilling, steaming, smoking and stewing. However, chicken and poultry are not popular in Korea but recently there is a rise in the consumption of chicken and ducks [11]. Japan is made up of several islands and the greatest natural resource here is the sea. Japan is proved to be one of the richest fishing grounds in the globe [12]. Japanese cuisine is based mainly on fish meat than any other kind of meat, unlike other nations. Buddhism and political idealism have also contributed to the consumption of fish over other kinds of meat [13]. However, the statistics show that there is a rapid increase in the imports of meat and poultry. The southeast Asian countries consume meat to a very less extent in comparison to east Asian countries. The annual consumption of meat in southeast Asian countries is almost less than half of east Asian countries [14]. From the above discussion, it will be clear that meat has very large importance in various cultures and countries. It has become an irreplaceable part of their culture and habits. Meat production has grown two-fold in just 30 years from 1988 and has come to four times since the 1960s. the consumption of meat is expected to reach 570 million tons by the year 2050. This is almost twice of consumption rate in the year 2008. As there will be an increase in the population, it will become necessary for humankind to adapt to a sustainable food supply. The major meat-consuming countries are the US and Australia consuming approximately 220 kilos per person per year. However, some countries in Asia and Africa have a consumption rate of fewer than 20 kilos per person per year [15].

Unfortunately, there are several problems associated with meat production and meat consumptions. Meat said to be a very inefficient food option when we talk about sustainable food options. The amount of energy, water and land required to produce a certain amount of meat is much more in comparison to any other food. In other words, meat has a higher “energy footprint” than other food products [15]. By 2050, the human population is expected to reach above 10 billion. It will be very difficult to feed all of them considering the current eating habits in western countries [15].

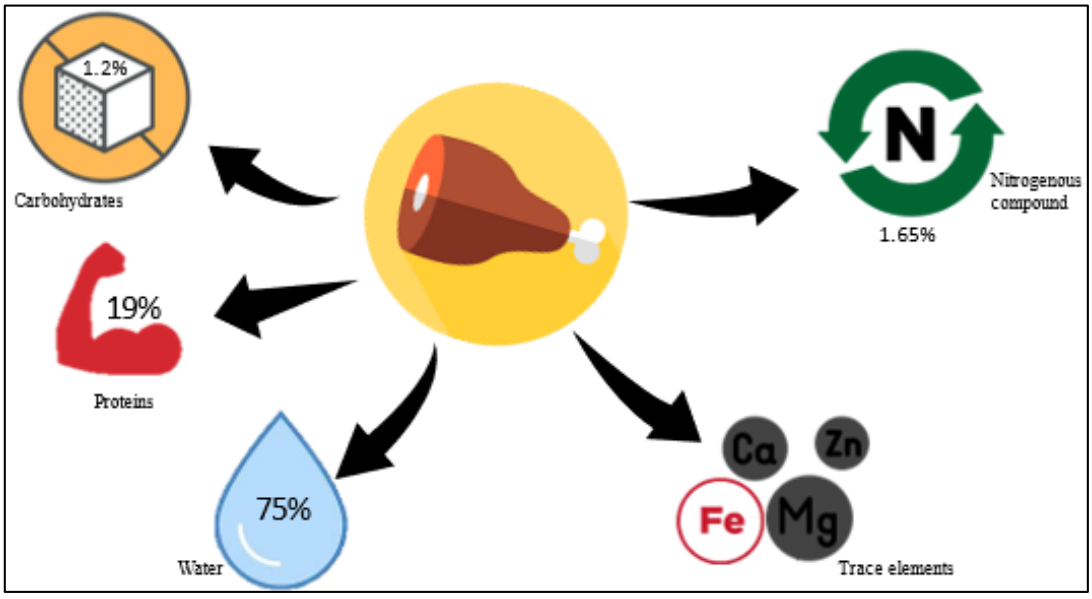

Fig 1: Meat as a source of essential nutrients

Discussion on problems associated with meat consumption

Meat is proved to be having all necessary nutrients required in a complete diet, from the scientific point of view. Meat does contain vitamins, aminoacids and minerals, apart from carbohydrates and high protein [16]. However, the production of this meat requires a large amount of energy, water and land. Apart from this animal husbandry industry is said to be the largest contributors to greenhouse gases. Not only that, but eating animals has also contributed tothe development of zoonotic diseases in the large course of time. Many outbreaks of deadly diseases are found to be coming from animal sources. Let’s discuss these problems in detail.

Zoonotic diseases and other diseases associated with meat consumption

Zoonotic diseases are those diseases that are acquired from another animal or species. These diseases transmit to other species by vector or causative parasite. These diseases are transmitted to people because of the eating of improperly cooked meat, eating contaminated animal food, etc. Only 13 major zoonotic diseases result in 2.2 million deaths in a year in a population with lower income [17]. Eating meat with adequate safety is of big concern and must receive enough attention [18]. Meat safety measures are to be given importance right from production to consumption, which is an important

pre-requisite action [18]. Consumption of red and processed meat is directly correlated to various disease which may become life-threatening [19]. Apart from that, meat products are associated with a high amount of cholesterol and saturated fatty acids, which may lead to coronary heart diseases and diabetes if consumed in large amount [20]. Although meat intake is also correlated with weight gain which may further lead to obesity [21]. Lastly, as there was high use of antibiotics in the processing of industrial meat, which led to the development of antibiotic-resistant bacteria in our environment.

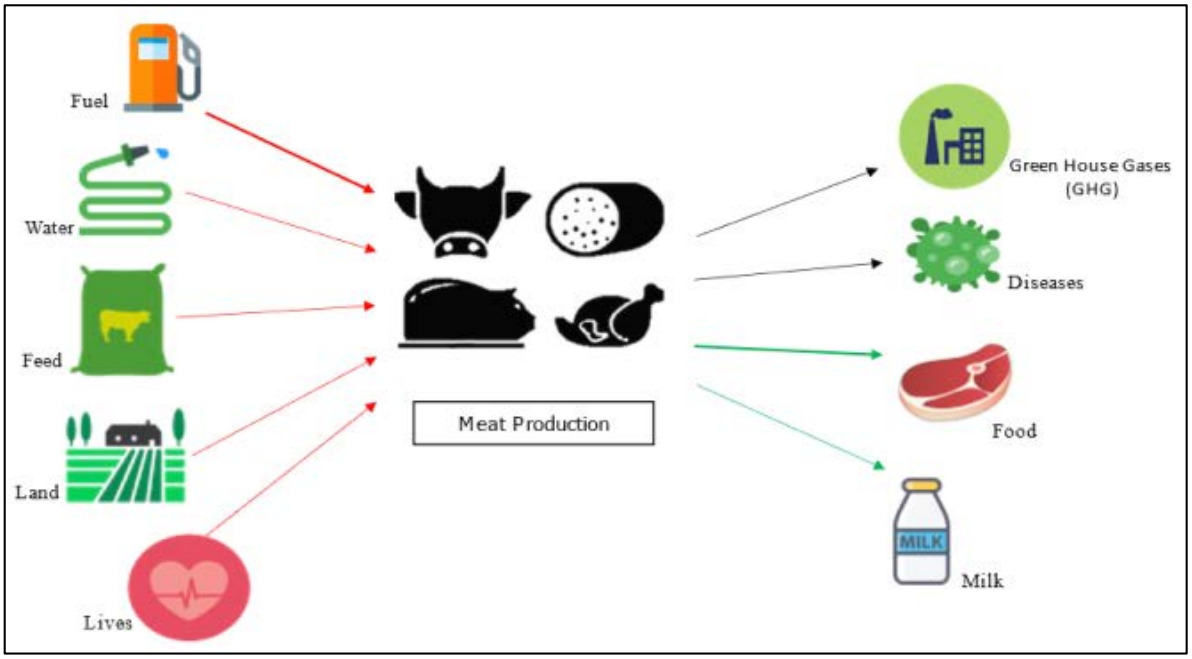

Fig 2: Pictorial representation of meat as a unsustainable source

Climate change

Brian Henning correctly said in one of his articles, Standing in Livestock's 'Long Shadow' that "the food we eat contributes more to global climate change than what we drive or the energy we use". Several kinds of research have already proved that the agricultural activities, including livestock rearing contributes much more in the release of greenhouse gas emission than the contribution of power generation activities and transportation activities [22]. The contribution of agriculture to global emission is around one-third of total greenhouse gas emissions [23]. However, no one talks about the emissions contributed by livestock production. It accounts for approximately 18% of global anthropogenic greenhouse gas emissions [24, 25]. Livestock production also indirectly contributes 9% of direct carbon dioxide emission because of the burning of biomass due to deforestation to prepare land for feed crop and animal rearing. Meat production has a much larger contribution tothe emission of methane gas, a high heat-trapping gas. Methane gas is produced by various natural and human activities. However, one of the major sources of methane is enteric fermentation (bovine flatulence) and waste treatment [26]. Methane is far more potent in trapping heat in comparison to carbon dioxide. Even though it is present in less amount, but can entrap 23% more heat comparatively. Methane is normally not absorbed by the biota unlike carbon dioxide; hence it stays in the atmosphere for approximately 12 years. After calculating the footprint of livestock production interms of carbon dioxide equivalent, the study shows that the production of 1kg of beef in the US corresponds to 14.8kg of carbondioxide. Whereas 1 gallon of gasoline leads to the emission of 2.4kg of carbondioxide. So, to produce 1kg of beef will be equivalent to the driving of an average American car for 300Km. and has a similar impact on the environment which requires 6.2 gallons of gasoline [27]. An estimation says that the emission of methane and nitrogen dioxide by livestock and agricultural practices respectively will increase by 60%, mainly because of an increase in the number of ruminants in east Asia and sub-Sahara Africa [28]. It is estimated that, by 2050, animal product processes will contribute to almost 80% of global greenhouse gas emissions if the practices increase with the same rate.[29,30] It was noted that the type of production system also affects the contribution of animal rearing, towards global greenhouse gas emissions [31].

Water and land usage

Meat consumption has a large impact on available land and water resources [32]. About 35% of cropland and 20% of clean water is dedicated tothe feeding of cattle and animal rearing. In countries like Europe, more than 60% of cropland is dedicated to animal meat production [33]. In comparison to land usage of animal meat production, the land usage for vegetal production accounts very less [34, 35]. Apart from that, there are other indirect impacts on the environment because of overgrazing leading to ecosystem changes. Water and land pollution also occur due to improper handling of animal waste and air pollution occur due to ammoniac release from intensive farming units mainly for the poultry [36]. A few years back, livestock used to contribute more than 85% of deforestation in South America [37]. In 2025, it was estimated that there will be water stress experienced by around 65% of the world's population and by 2050, more than 3-5 billion people will have to face severe stress due to scarcity of water [26]. Domestic use of freshwater is around 10% but around 66-70% of water resources are contributed to agriculture from which the hidden figure is for livestock production [22]. Based on the studies conducted by National Geographic in 2010, a half kilogram of beef requires water of around 1799gallons,

one pound of pork needs 576 gallons, one pound of chicken will need 468 gallons and 216 gallons for one pound of soybean. It required ten times the water for producing the same amount of animal protein as it requires for plant or grain protein [38]. Not only the water requirements but the excreta of livestock are collected in the US and filled in an empty pond called lagoons. It is simply a pond of pee and poop in a large open pond that is not at all send to waste treatment plants either like human waste processing plants. Livestock produce almost 10times more waste than a human does [39].

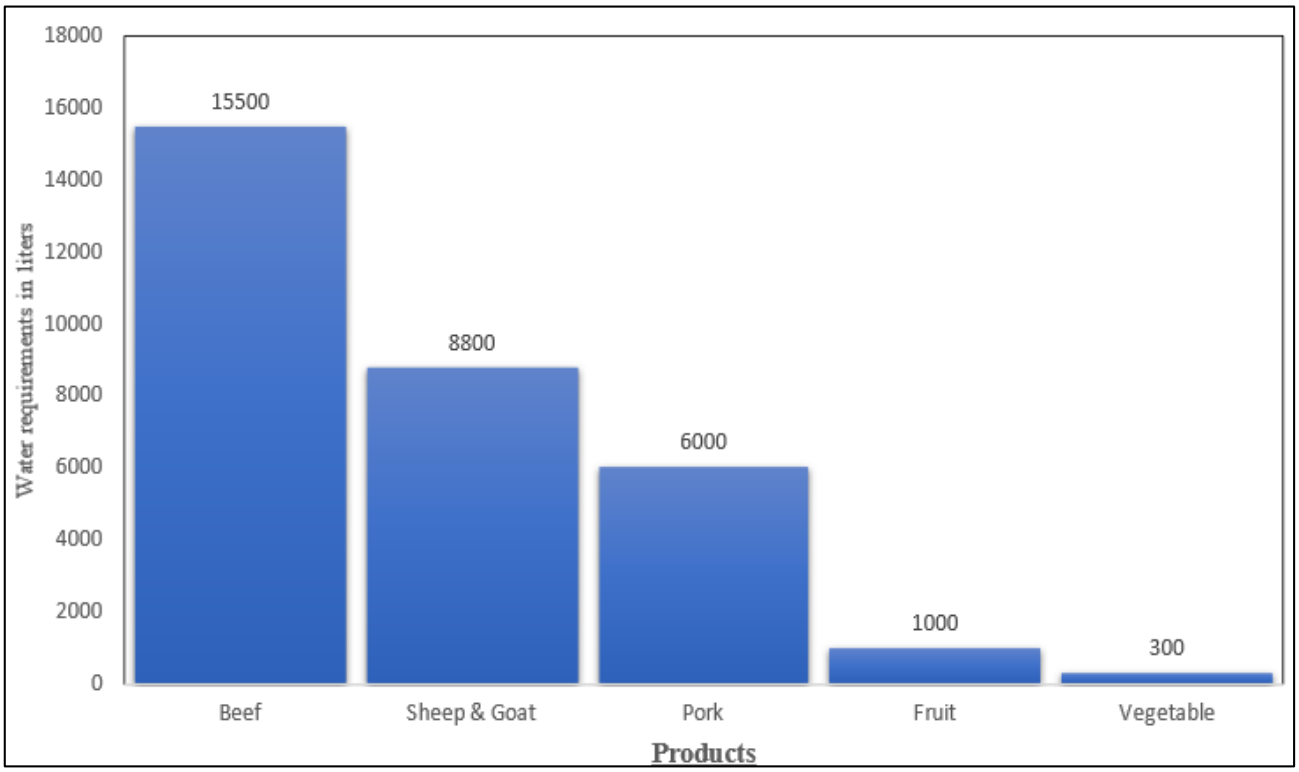

Fig 3: Graphical representation of water requirement to produce 1 Kg of different food products

Why meat analogue?

The human population is growing rapidly and also the demand for the food supply. In future, it will be necessary for humans to give up on eating habits which are being followed since the beginning of the 20th century. We will have to find a sustainable option for everyone to eat which will satisfy our demand without considerable impact on our health, environment and natural resources. Because of animal welfare and production practices, the planet issues are rising continuously.[4] Meat production requires a very high amount of arable land, water, feed and other resources [4]. However, we cannot completely ignore the factors such as the cultural importance of meat consumption or eating habits of people eating meat from generations. Although we can still provide an option or a substitute that may fulfil the same perception of eating meat without actually eating one. Meat analogue is food products designed for the same purpose. Meat analogue is edible substitutes of meat, which looks, feels and tastes similar to meat. In other words, we can consider it as a sustainable option for meat products. Meat analogue is also known as a meat alternative, mock meat, faux meat etc. The research community is now targeting refining the process and production system to obtain an efficient and novel way to improve the food eating habits of people and also respecting the cultural importance.

Composition of meat analogue

The meat analogue is expected to mimic the sensory properties of meat. It is a big task for a food technologist to develop the exact or similar texture, taste and mouth feel of meat in its analogue. One must first understand the composition and their role in the food to mimic it. Meat analogue is produced from various constituents as suggested by Egbert and Borders (2006) [40], which includes 50-80% water, 10-25% plant proteins for texture, 4-29% other proteins, 3-10% flavoring agents, 0-15% oil (plant source), 1-5% binding agent and less than 0.55 coloring agent. Water is a major part of the constituents that contribute to the desired juiciness and shape-giving ability. It also acts as an emulsifier for all the ingredients. Proteins have nutritional importance and are responsible for the desired texture, mouthfeel and appearance. Protein kind is very important as the hydration, solubility, interfacial properties, flavor binding, and gelation properties are to be considered. The specific plant protein source is selected based on the desired texture. For the production of vegan meat analogue, the textured protein source from plants is used completely [41]. Soybean proteins, wheat gluten, cottonseed proteins, and other plant proteins are also used as primary proteins [42]. Some of the plant-based sources of proteins lack essential amino acid, unlike the most animal source of protein [43]. Some minor components are added in some amount to improve the final appearance and texture of the meat analogue such as protein isolates from soy, wheat gluten, egg white and binding agents like hydrocolloids and starch. They also function as water-holding material because of their very good water holding capacity. The best and preferred texture parameters are determined by consumers acceptance [44]. Flavoring and coloring components will play a major role as consumer acceptance will be increased based on the flavor and aroma of the finished product [45]. The processing of product will have physical, chemical and nutritional changes in the proteins and other

constituents [46].

Author opinion for challenges

The most challenging part of producing meat analogue is to recreate the sensory properties of meat in something made from vegetables. However, using various processing techniques such as extrusion, shearing and toa lesser extend spinning, it is possible to mimic the original meat using plant-based ingredients. The nutritional aspect of meat analogue can be taken care of by using multiple plants such as legumes. However, they may lead to the production of off-flavors. There will be a need for masking or reduction in off-flavor components from the ingredients. Apart from the taste the appearance place much more impact. Heat stable coloring agents may play an important role as there should be color change during the process of cooking which should resemble the color change of meat while cooking or frying. The perceiving of the meat analogue product in the mouth is the next challenge. A mouthfeel of juiciness and tenderness is a desired characteristic of meat analogue. Various ways are being used such as moderating the water holding capacity of ingredients may be used for this purpose. Meat is mainly consumed for its rich source of proteins and amino acids. Some of the meat analogues contain protein from egg and milk. However, if the vegetable proteins are used then it is fortified with missing nutrients such as iron. Apart from all these production challenges, the bigger challenges are to make it sustainable. People aware of the environmental problems associated with meat consumption needs it to be sustainable and will ask for the carbon footprint of the food product.

Algal protein as a composition of meat analogue

Algae are photosynthetic eukaryotic organisms. The microalgae are very rich in proteins. They serve as valuable food ingredient and coloring agents. However, they are utilized mainly in less amount. They possess various properties such as foaming, gelation and emulsification. The algal drymass may have approximately 30-50% crude protein. Depending on the species and growing condition, the composition may vary [47]. About 50 years back, technologies are being developed to mass-produce the protein-rich micro-algae to bridge the proteingap in the diet. A lot of studies found that the algae proteins are of high quality and possess high nutritional significance [48]. Despite that, algal proteins have not gained much importance yet. This is because of the green and yellowish pigmentation, fishy smell and dry powder-like consistency. Several attempts are made to incorporate it into food items like noodles, bread and ravioli by processing it using heating, baking and mixing. However, the result came out to be unpalatable. Another reason for not gaining importance is the restrictions in developed countries for unknown ingredients. Last but not the least, the production cost of algae protein and purification was too high which will ultimately increase the cost of the food product aswell. The use of algal protein in meat analogue will put forward some big challenges for food technologists. However, there can be a solution to some problems such as using processing technologies such as beaching, emulsification and extrusion have shown considerable results. Utilization of specific cyanobacteria results in no or less pigmenting property and off flavors. much research needs to be done in identifying the algae for this purpose and also to mass-produce it. Another challenge is that the protein should be heat stable as during cooking of meat analogue, this should remain stable through the process [48].

Conclusion

Meat has such a huge demand in public and it has been constantly rising. It has expected to double by 2050. However, meat production at the industrial level has put a big toll on the earth in various ways. A lot of problems arise because of mass production of livestock such as global warming, freshwater shortage, large land usage, deforestation, extinction of species, the spread of zoonotic diseases, large waste production etc. Much research has needed dedicated to the production of artificial meat, mock meat and vegan meat which are collectively known as meat analogues. It is gradually gaining importance in developed countries and several companies are already into the market of selling plant-based meat. Meat has been consumed for its protein source apart from its other nutritional aspects. Meat analogues are produced using several ingredients where the different component is obtained from different sources. Protein is obtained mainly from protein-rich crop such as soybean, legumes etc. The idea of utilizing the algal protein as the protein source in the meat analogue has been discussed in this paper. However, several challenges such as pigment color and taste need to be overcome before the incorporation. Apart from this, the production of algal protein is a costly process which is another challenge for it. But large production of algal protein can reduce the cost of production.

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