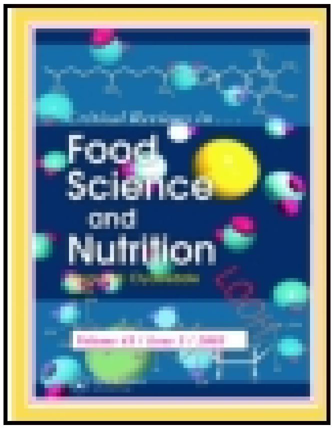



Critical Reviews in Food Science and Nutrition
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/bfsn20

# Meat analogues: Health Promising Sustainable Meat Substitutes

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Accepted author version posted online: 21 Apr 2015.

# Meat analogues: Health promising sustainable meat substitutes

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## ABSTRACT

There is a scarcity of protein of high biological value due to rapid increase in the world population and limited natural resources. Meat is a good source of protein of high biological value but converting the vegetable protein into animal protein is not economical. There is a trend of production of healthy and delicious meat free food for satisfaction of vegetarian and personal well beings. This resulted in increasing use of low cost vegetable protein such as textured soy protein, mushroom, wheat gluten, pulses etc as a substitute for animal-protein. These simulated meat-like products, with similar texture, flavour, colour and nutritive value can be substituted directly for meat to all sections of the society.

**Keywords:** Meat analogues, vegetable proteins, product profile, sensory attributes

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**INTRODUCTION**

Meat has a distinct position in the food basket and has been widely consumed by the humans since pre-historic era due to readily source of energy, high quality proteins, palatability as well as images of strength and power (Fiddes, 1991; Latvala et al., 2012). The per capita consumption of meat has more than doubled over 1961 to 2007 and recorded rapid growth in developing countries in comparison to developed countries.

It is expected that increasing population, urbanization, industrialization, education and rise in income will causes 72% more demands of meat consumption by 2030 (Steinfeld et al., 2006; Faisla, 2008). Steinfeld et al. (2006) and Bruinsma (2009) projected the doubling of animal products production from 229 billion kg for 6.0 billion populations in 2000 to 465 billion kg animal products for 9.1billion populations by the year 2050. Meat production has increased 5-13% in last decade and reached close to its maximum production (Post, 2012). Recently it has been noticed that ethical and environmental concerns of meat production and consumption has been in focus (European Commission, 2005; Mayfield et al., 2007; McEachern and Schroder, 2002).

Food security is a major concern for the increasing world population. This has put a severe pressure on the natural resources including agricultural land and water to grow the food crops. A major chunk of the world population is facing starvation which demands more production of staple crops (Datar and Betti, 2010). The requirement of food is predicted to grow by 70% by 2050 due to further addition of 2.3 billion populations (Bruinsma, 2009). At present, out of total energy and freshwater consumption, 20% of electricity and 70% of freshwater is consumed for the production of food crops (Green et al., 2006).

For production of meat, food animals are reared and slaughtered. The rearing of food animals for meat production is basically a method of converting vegetable protein into meat proteins through food animals. The rearing of food animals for meat need natural resources inputs in the form of water, feed, fodder etc. The per unit production of vegetable crops needs comparatively less natural inputs viz. water, land, energy for production as compared to per unit production of meat. Thus, meat production is considered as inefficient utilization of plant protein into animal protein and it takes major chunks of environmental resources such as land, water and energy (Raney et al., 2009; Steinfeld et al., 2006; Bruinsma, 2009). According to Stockholm International Water Institute, production of 1Kg grain fed beef require 5-40 times more water than to produce 1kg cereal grains (SIWI-IWMI, 2004). According to one estimate, two lakh litres of water is consumed for production of one kg beef (Brown, 2009; Ye and Van Rast, 2009). Pimmentel and Pimmentel (2003) estimated that during the production of meat, 100 times more water is consumed as compared to water consumed during the production of food crops. In terms of human diet, it was estimated that during the production of meaty diets per person per year, two million litres of water was needed which is just double of the water required for vegetarian diet per person per year (Smil, 2000).

Meat production is also responsible for increase in the greenhouse gas (GHG) emission. The contribution of livestock to the emission of three major greenhouse gases carbon dioxide, methane and nitrous oxide, is 9%, 39% and 65% respectively (FAO, 2006). Out of total grain and soya produced, 40% of total grains and 75% of total soya is utilized for animal feeding. Out of total area of planet, 30% is devoted for animal production which counts about 70% of the total arable land. Further, the rapid expansion of the livestock farming has put more pressure on the available natural resources and considered as a key factor in deforestation (Pimmental and Pimmental., 2003; Smil, 2000; Steinfeld et al., 2006; Aiking, 2011). Taking into account the prevailing environmental and animal welfare aspects, it would be difficult to meet food security targets but its nutritional aspects could be easily fulfilled from non-meat plant protein (Bittman, 2008).

Post (2012) enlisted three major concerns related to the meat production as

i. Environmental issues- such as environmental pollution, deforestation, depletion of natural resources etc.

ii. Animal welfare issue- such as cruelty and unethical treatment of animals during rearing, transportation and slaughter.

iii. Public health issues- such as overconsumption of meat is responsible for a quarter of all ischemic heart disease responsible for over 1.8 million death annually (Key et al. 1999). Larsson and Wolk (2006) suggest that consumption of 120 g red meat/day or 30 g processed meat/day would significantly raise the relative risk of colorectal cancer. The food borne pathogens found in meats, such as *Salmonella*, *Campylobacter* and *E. coli*, are responsible for millions of episodes of illness each year (CDC, 2012).

Thus, the inefficient utilization of precious natural resources makes the production of meat at the cost of staple grain a debatable issue (Hoek et al., 2011; McMichael et al., 2007). The huge environmental and socio-economic issues such as deforestation, food security, environmental pollution etc have created awareness among the consumers for sustainable methods of food productions (Aiking and de Boer, 2006). It has fostered great interest in the possibility of fabricating protein-rich food from plant sources in a palatable form and shifted the




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mindset of policy makers and scientists towards the development of suitable alternative of simulated meat like products, with controlled texture, flavour, colour and nutritive value. These alternative products for meat are meat alternatives/ meat substitute/ meat analogue/ fox meat. These products are in infant stage of development and at present accounts nearly 1-2 % of total meat market (De Bakker and Dagevos, 2010). However, due to intrinsic cheapness of proteins from vegetable origin and nutritional factors, the use of such products is bound to increase as substitutes for expensive proteins of animal origin.



**MEAT ANALOGUE**

Meat analogue is a food product that approximates the aesthetic qualities and /or chemical characteristics of certain types of meat. These are made from non-animal protein and its appearance and smell are very much similar to meat. US legislation defines a food as 'imitation' if it is nutritionally inferior and as 'substitute' if it is nutritionally equivalent. Such foods are attractive to the processing industry because of cost advantages, comparatively stable price due to less liable to seasonal fluctuations in supply, longer shelf life and easier storage. Although the term meat analogue has been mostly used for products based on spun protein filaments, it also includes many others generalized products as textured vegetable proteins. Meat analogues are the one of the best suitable method in which vegetable proteins and unconventional proteins can be introduced and the underlying impetus remains the utilization of a wider range of proteins for human food (Tombs, 1974).

The evolution of protein products of non animal origin could be of three main types viz. meat extender, meat analogues and completely new protein products not associated with meat.

 

Spicer (1971) reported that the use of low cost meat analogues in developed as well as developing countries was evolved because of the large numbers of relatively poor people, and competition of food with consumer goods in the family budget. As true vegetarians constituted just 1ï 2% of the United States population, other factors must be at play to contribute to meat-analogue interest in United States. The reasons frequently cited were health and nutritional benefits, environmental considerations, religious beliefs, and animal rights (Food and Nutritional Science (FNS) Programme, 2000).



## KEY INGREDIENTS

The vegetarian diet is generally rich in fibres, fruits and vegetables. These ingredients are known to possess health benefits. Meat analogues can be obtained from an ever-increasing number of protein sources. Vegetable proteins are currently the main source of material for meat analogues such as glutens of wheat and globulins of groundnut, cottonseed, peanut, sesame, yeast and soybean. The main ingredients used in preparation of meat analogues are soya protein, pulses, nuts, cereal proteins, vegetables, mycoproteins but the wider consumer choices resulted inclusion of newer ingredients in meat analogues. At present, however, the bulk of production is based on soybeans, which is probably still the cheapest common source of protein raw materials. Meat analogues could be manufactured to have protein of high biological value, and could enrich a monotonous diet based on plant protein. Soya and other oilseed extracts as well as proteins produced by fermentation based on various substrates and microorganisms would be mostly used for meat analogue production.

Though, vegetable proteins are the main source of material for meat analogues but algae, yeast, mushroom and bacteria would probably supplement them in near future because they multiply rapidly without land and adjust very well to consumer taste (Hegenbart, 2002). Meat analogues could also be prepared by hydrating a textured vegetable protein, preparing a protein base containing vital wheat gluten, milk protein and water and combining the hydrated vegetable protein and protein base (Howse et al., 2005). The very common human non-digestive dietary fiber-konjac fiber products in the market for the past few years were other mock-meat products for consumers to choose from in terms of taste and health reasons. Howsam (1976) reported that the industrial manufacture of meat analogue products from protein-rich precursor materials, including plant based precursors such as cereal grain gluten (of wheat, rice, or maize; vital or with residual starch), defatted oil seed, cereal and bean flours, meals and derivatives (e.g. defatted soya flour, soya protein concentrates, wheat flour), or animal based precursors such as meat by-products obtained by mechanical separation, fish meal, dried egg white and others, alone or in combination should be taken up on a regular basis.

The key ingredients to be used during preparation of meat analogues are as follows:

1. Soya protein
2. Mushroom
3. Wheat gluten
4. Egg albumen
5. Carbohydates and gum
6. Flavouring and other miscellaneous compounds

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## 1. Soy protein

Soya is known to have high quality nutritional and functional benefits. It is widely used for partial or complete replacement of meat due to its comparative nutrient contents and lesser chances of cardiovascular diseases. Further it was also reported that the story of soya as a meat alternative had been one of extension and substitution. Beloglavec (1974) reported that meat like products could be obtained from an ever increasing number of protein sources and soyabean was the cheapest and most common source of protein. On PDCAAS (Protein Digestibility Corrected Amino Acid Score) scale soya protein was reported to be equivalent to animal protein with a score of 1.0, the highest possible rating (Hoffman and Falvo, 2004). Thus soya protein is a very attractive alternative for those seeking non-animal sources of protein in their diet and those who are lactose intolerant. Protein isolates of soybean is of comparable biological value to that of meat. Soybeans are also a good source of calcium and linoleic acid. Alpha-linoleic, an essential fatty acid, is an omega-3 fatty acid present in soybeans. A consistent consumption of soya foods also confers certain health benefits. Thus, soya foods that provide a good source of nutrition are especially vital for vegetarians, and provide a good substitute for meat products (Wardlaw and Kessel 2002).

Harland (2002) analyzed the Market trends for soya-based food products (meat replacers and dairy alternatives) in the UK and revealed the recent growth in the market for soya foods is among health-conscious consumers. It is valuable in the manufacture of emulsion-type products because of its power to emulsify, stabilize, texture and hydrate the products. Textured Vegetable Protein (TVP), such as soy meat analogues, provides a good source of protein that is readily digestible. In adults, protein digestibility and nitrogen balance (g N/ day) was 66.1% and 1.16 for textured vegetable protein from defatted soy flour and 63.4% and 1.31 g N/ day in TVP from soy protein concentrate in comparison to beef that possessed 73.2% protein digestibility and 0.42 g N/day (Cheftel 1986).

Soya protein isolates are widely used for preparation of soya based meat alternatives along with wheat gluten and other vegetable proteins (Morr and Ha, 1991). The nutritional quality of products prepared from soya protein isolates are inferior to the product prepared from minimally processed soya flours (Alfred et al., 2004). The soya meat alternatives were mostly prepared by extrusion process in which the texture of the product remains fibrous due to disulfide bonding and resemble the meat texture (Cumming et al, 1973). Meat analogues can be produced at either low moisture conditions, fewer than 35% by use of a single-screw extruder, or at high moisture conditions, above 50% by use of a twin-screw extruder (Lin et al, 2000; Lin et al, 2002).

Huffman and Powell (1970) reported soya proteins as widely used vegetable protein in the formulation of food products. It is used in various physical forms i.e. soya flour, soyabits, isolated soya protein, spray dried soya milk and texturized soya proteins. Ishizuka and Akoi (1986) patented simulated ground meat analogue from tofu, by adjusting the pH of a soya milk to 5.6-6.2, coagulating the soya milk to from tofu, from pressing and dehydrating the tofu to obtain a solid content range of 35-50%, shaping the pressed tofu into a form of similar to ground meat and heating the product. Williamson et al. (2005) compared the tofu preloads and mycoprotein with chicken preload and reported a lower food intake shortly after consuming the preload at lunch.

Food intake following consumption of mycoprotein and tofu did not differ and participants did not compensate for lower food intake at lunch by consuming more food at dinner. The findings suggested that tofu and mycoprotein had satiating properties that persisted for several hours after a meal. These findings had significant implications for the development of foods that are low in kilojoules, but are also filling.

## 2. Mushroom

The natural protein of mushroom is fibrous in nature and its incorporation provides chewability of the products (Naylor et al., 2001). The cell walls of hyphae are rich in dietary fibres whereas polyunsaturated fatty acids are abundant in cell membranes. The cytoplasm is rich in high quality proteins. The mycoprotein can reduce the harmful LDLs (low density lipoproteins) and enhances the beneficial HDLs (high density lipoproteins) (Rodgers, 2001). Mushrooms could contribute to fulfill our daily requirements of protein, minerals and vitamins.

The first commercial meat analogues such as burger patties and sausages with mycelia were made from the edible filamentous fungi *Fusarium graminearu*. The meaty flavour of these products attributed to the presence of sulfur containing amino acids and glutamic acid in fungi (Trincy et al., 1994). The taste of mushroom derived products is better than other plant derived products. The meat alternatives are prepared from mycoprotein by mixing the fermented mushroom with egg and other seasonings/ flavourings. These are widely used in European countries as alternative to beef and chicken. However, the wide spread public perception of the *Fusarium* as pathogenic and not a true mold has forced the researchers and food technologist to search a better alternative.

The preference of fungal protein over bacterial and vegetable proteins can be summarized as follows-

a) Mushroom flavour of fungal protein is more acceptable as compared to beany flavour of textured soy protein.
b) Fungal protein gave convincing meat, poultry and fish analogues by alignment of the protein filaments with fibrous or flaky texture (Anon, 1981).
c) The most of mycoproteins are tasteless, colourless and unpalatable with texture similar to meat fibre but with added flavouring and colouring it could be made into a passable imitation of fish, chicken, veal or ham.
d) Health benefits and antitumor effect of mushroom



Mycoprotein was the first fungal food to be produced for human consumption marketed on a limited scale in UK. Newmark (1980) described the process of production of processed mycelia of A35 strain of *Fusarium graminearum*. Uzunov and Colova (1972) described the organoleptic and keeping quality of mushroom as raw material for sausage. They also noted the large quantities of proteins which could replace part of the raw meat and easily mixed with meat to form a homogeneous finely chopped material. The developed product is having the light grey colour and specific flavour imparted by the mushrooms. Chevrolet (1988) patented a composition for making of meat like products by using the edible mushroom, gelling agent (polysaccharides undergoing gelation not reversible by heating), texturing agent (proteins) and flavourings. Kumar et al. (2011) reported that 22.5% mushroom replacing texturized soya protein increased the sensory attributes of analogue meat nuggets due to increase in flavour and overall acceptability.

## 3. Wheat gluten

Wheat gluten is a cohesive, visco-elastic complex of enigmatic complex proteins prepared as byproduct during isolation of starch from wheat flour. It is widely used in meat analogues preparation due to its binding, dough forming and leavening ability (Rizvi et al., 1980; Dayab et al., 2006). The dough forming properties of wheat flour is due to wheat gluten (Day et al.,2005). Gluten is finding its way to inclusion in meat analogues due to its functional properties as solubility, viscosity, swelling, nutritional quality), possibility of scale modifications and modest price than soya, caseinate and mushroom proteins (Sarkki, 1979; Dayab et al., 2006). It is rich in glutamine, a muscle building amino acids and deficient in lysine and threonine contents. Gluten (vital, de-vital or modified) was found increasing use as a food ingredient to provide a range of functional properties at a more modest price than competitors such as milk and soy proteins. The past five decades had seen the rise of gluten as a commodity. The large-scale industrial separation of wheat starch from gluten and the controlled drying of the gluten retained its functional properties.

Olavarria (1981) patented protein binder compositions for texturized proteins comprising 10-20 % gluten, 10-20% whey proteins, 1-5% albumin (dried egg white) and sufficient liquid (milk or water, preferably the latter). Nguyen (1988) patented meat analogue resembling chicken breast from wheat gluten, wheat or soy flour. Dry powder blend of 80% wheat gluten, 11%wheat flour, 9% vegetable oil was mixed and water sprayed on the mixture which contributed 50%by weight. Dough was prepared and heated by conventional or microwave means. The resultant products lacked the unpleasant flavour of soy based meat analogues. Kumar et. al. (2009) and

Kumar et. al. (2012) reported that the incorporation of wheat gluten in analogue meat nuggets improved almost all sensory traits. Sarkki (1979) reported increase in functional as well as baking properties of the analogue meat product as a result of addition of wheat gluten. The addition of 10-20% wheat gluten in meat substitutes has increased the flavour and colour scores of the product (Olavarria, 1981).

## 4. Egg albumen

Egg white (albumen/glair/glaire) is the common name for clear liquid contained within an egg. The incorporation of egg albumen in meat analogues contributes binding as well as bite during the eating experience. It also enhanced protein content of analogue meat nuggets. Ovalbumin, a globular monomeric phosphoglycoprotein containing free sulfhydryl groups has the ability to form heat-induced gels contributing one of the most important functional properties of egg albumen (Jerez et al., 2007 and Eleya et al., 2004). Globular protein molecules unfold partially to a molten globule structure increasing viscosity (consistency) relative to compact folded polymers of the same molecular weight thus add to the binding effect of globular proteins (Damodaran and Paraf, 1997).



The incorporation of egg albumen had a marked effect on the phsico-chemical properties of analogue meat products but fat levels were least influenced by the variation in incorporation of egg albumen in the products (Kumar et. al., 2010). They also revealed inconsistent but marked influence of egg albumen incorporation on sensory attributes of analogue meat nuggets. Jao et al. (1980) reported that effects of egg white content and cooking time were exponentially related to the hardness whereas salt content was linearly proportional to the logarithm of hardness.

Response surface analysis revealed that egg white usage could be greatly reduced if salt content and cooking time were manipulated. This study provided a model that could be used to optimize a process for producing meat loaf analogue. Rizvi (1977) reported increased brown background colour and gel like appearance on increasing temperature and pH. Brown particle colour and number increased with gluten level in the product, whereas particle size decreased as egg albumen content increased. Hardness, gumminess and chewiness were found to be exponentially correlated with egg albumen content, pH and their interaction. Elasticity increased with gluten whereas cohesiveness depended on albumen level.



**5. Carbohydrates and gum**

Proteins have technological limitations such as resistance to heat treatments, compatibility with the other constituents as flavour components etc., restricting their use in meat analogues (Lucca and Tepper, 1994; Linden and Lorient, 1999) whereas results obtained from carbohydrates are more satisfactory (Akoh, 1998). Carbohydrate gums are commonly used by the food industry as texture modifying agents in many different types of products. Starch, the food reserve polysaccharide of plants is a commonly used food hydrocolloid. Starches and maltodextrins are polymers of glucose which on hydration form gel and mimic fat like texture. Therefore, carbohydrates such as starches, gums, hydrocolloids, maltodextrin, dextrin, polydextrose, pectin, inulin, hemicelluloses and cellulose gels are very frequently used as fat substitutes in low-fat food products (Shand et al.,1990; Keeton, 1994 ). Starches are popular not only for their functional properties but also for their low cost alternatives (Yang et al., 1995; Jimenez Colmenero, 1996). Glicksman (1976) reported the use of hydrocolloids, or gums, at less than or equal to 1% to impart a great variety of desirable characteristics to foodstuffs. Pearson and Gillett (1997) described softening of the products on addition of sucrose by counteracting the harsh hardening effect of salt by preventing some moisture removal and enhanced the product shelf life by inhibiting bacterial growth.

**6. Flavourings and miscellaneous ingredients**

Flavour is an important sensory attributes which determine the acceptability of the products. A meat analogue should have meaty flavour. Lot of research work is going on to develop artificial meaty flavours. Hasida (1974) reported that for flavour potentiation of meat analogues vegetable protein products (acceptability of meat analogues, undesirable soy protein odour), chemical condiments (flavour effect, glutamic acid and 5-ribonucleotides in food stuff, application for food processing) were used. Hsieh et al. (1980) developed a synthetic meat flavour by surface response methodology, consisted of an autoclaved mixture of simple sugars, amino acids, 5-nucleotides, glycoprotein, monosodium glutamate and salt with fat an optional component. Sulphur containing amino acids and simple sugars played an important role in flavour development, whereas the other components either masked the harsh sulphury taste or enhanced the meaty flavour. Anon (1981) made a mushroom concentrate, produced from fresh mushrooms, gave an intense mushroom flavour to formulated foods at levels of 1-3% and at less than 1%, the concentrate acted as a flavour enhancer, and successfully replaced replace monosodium glutamate or hydrolysed vegetable protein. Spencer et al.(1982) patented a flavouring composition of 2-(alpha-mercaptoalkyl)-3-thiazoline is described to impart a meaty, saute onion flavour and aroma at the level of 0.5-50 ppm in the food. Kibler et al. (1988) reported production of high concentration of 1-octen-3-ol, a major volatile flavouring component of many mushroom species upon heating of homogenized mushrooms in aqueous medium containing a water-soluble salt of linoleic acid and oxygen. Chen and Soucie (1985) in their patented work made edible whey protein/xanthan gum fibres by precipitation from a solution containing whey protein (at least 20% and preferably >30%) by adjusting the pH to the appropriate iso-electric point and separating the fibres from the solution. The solution may include other (solubilized) proteins, such as egg white, and/or soya protein, casein and sodium caseinate. The fibres may be stabilized by heating at or more 70°C and flavoured to obtain meat analogues and seafood products.

Caseinate are present in milk in the form of a1, a2, b and k-casein. Commercially, caseinate are produced in numerous compounds viz., sodium, calcium, potassium and magnesium caseinate for food application (Giese, 1994). Sodium and potassium caseinate are more soluble and possess better functional properties than calcium caseinate (Kinsella, 1984). Jordan (1991) reported that functional ability of the caseinate lies in the unique distribution of the electric charges on the polymeric molecule, hydrogen bonding and richness of hydrophilic as well as lipophilic bonding sites. Singh et al. (1997) documented that caseinates proved to offer better functional qualities when used in combination with vegetable proteins in comminuted meat products. The emulsion stability of batter containing caseinate and refined wheat flour was significantly higher than batter without caseinate and refined wheat flour. Chen and Soucie (1985) patented the serum milk protein complex formation by adding xanthan gum, at a gum to protein ratio of 1:2 to 1:10, to whey, whey protein concentrate or whey ultrafiltrate. The mixture was acidified to the isoelectric point of the complex to form a fibre structure, which could be separated and used as a meat or fish analogue. Flavourings could be incorporated into the final products by adding them to the initial whey/xanthan gum mixture. Alternatively, proteins such as soyabean isolates could be incorporated in the whey/gum mixture. Yadav et al. (1986) described a method for producing vegetarian sausages from milk involves coagulating 1%-fat milk at $70^0$C with citric acid, pressing the coagulant, blending it with other ingredients and filling into a casing, cooking in pressurized steam, cooling and storing at 6-8 degrees C. The sausages contain approx. 5% fat, 20% protein and 45% total solids and they have good microbiological quality.

Carrageenan are sulfated high molecular weight polysaccharides extracted from red seaweeds (Rhodophyta). These are approved for use in food products as binder and extender in United States (9CFR 318.7; 9CFR 319.15) (USDA 1973). Carrageenan are of three types iota, kappa and lambda. Iota and kappa carrageenan act as gelling agents. The lambda type is non gelling and function as a thickner. Pannin et al. (1974) used carrageenan as a substitute for gelatin in concentration less than 0.3 percent whereas higher concentration had given better off flavour to the product. Carrageenan also successfully used to improve rheological properties and water binding capacity of low-fat emulsions. Foegeding and Ramsey (1987) reported that kappa carrageenan at 0.5 or 1 percent level was most effective among the varieties increasing hardness. Huffman et al. (1992) documented that iota carrageenan gels strongly with calcium ions to form a clear, elastic, syneresis free gel that resets after shear. Moreover, iota carrageenan has great ability to retain moisture.



## MEAT ANALOGUE VS MEAT PRODUCTS

The difference between the meat analogue and meat product is basically due to their compositional variations. Redman (2008) patented a method of manufacturing meat analogue containing between about 40% protein by mass in an extrusion cooker. The extrudate was held at ambient temperature and pressure conditions to facilitate the formation of a skin on the outer surface of the extrudate. The contraction of the cross-sectional area of the extrudate causes the 'skin' to wrinkle in a manner that gives the appearance of cooked muscle meat. Kumar et al. (2011) prepared meat analogue nuggets by incorporating texturized soya protein, mushroom, wheat gluten, singhara flour etc and compared with chicken nuggets (economy grade) for different physico-chemical properties, sensory attributes, lipid profile, calorific value, mineral profile including sodium and potassium. The pH, moisture, protein, fat, and cooking yield of chicken nuggets were significantly higher ($P<0.01$) as compared to analogue meat nuggets. Mean sensory scores for most of the attributes viz. flavour, juiciness, texture and overall acceptability were significantly higher ($P<0.05$) for chicken nuggets as compared to analogue meat nuggets, although general appearance and binding were comparable. Free fatty acids, total lipids, cholesterol content and calorific value of analogue meat nuggets were significantly lower ($P<0.05$) than chicken nuggets. Sodium content was significantly lower ($P<0.01$) for analogue meat nuggets as compared to chicken nuggets. Potassium, zinc, copper and iron contents were significantly higher for analogue meat nuggets as compared to chicken nuggets whereas lead and cadmium contents were comparable. Hegarty and Ahn (2006) reported higher potassium concentration of analogue meat as compared to meat. The meat analogs had a higher proportion of polyunsaturated fatty acids, and a higher concentration of potassium, calcium, and phosphorus than the ground beef. Protein quality of the meat analog was relatively high except methionine was the limiting essential amino acid. Heating to temperatures used in cooking did not greatly affect the amino acid profile or biological value of the meat analog or ground beef.

Texture is a sensory property of food that results from a multifaceted group of components and determined by using by sensory panels or instrumental techniques. Bourne (1978) reported that texture, appearance and flavour are the three major components of food acceptability. Morrow and Miller (1975) reported that in a 2 phase system of soya fibre-egg albumen (SE), fibre orientation and fibre density significantly affected the dynamic compressive modulus and creep shear modulus. It made possible to design a comparative bovine meat analogue by altering the density and orientation of fibres. Kumar et al. (2011) reported significantly higher ($P<0.05$) values for hardness, gumminess, chewiness, fructurability, springiness and cohesiveness for chicken nuggets as compared to analogue meat nuggets. Sung et al. (2001) reported that 15% mushroom in fish meat paste had highest values for strength, hardness, gumminess and brittleness whereas sensory analysis revealed that samples 5% mushroom in fish meat paste obtained the highest scores for taste, texture and overall acceptability. Flavour and colour scores were highest for fish pastes containing 20% mushroom. The use of rice flour and faba beans as a meat substitute in beef burgers lowered the cooking loss and shrinkage, improved the texture, kept the flavour and reduced the changes occurring in the peroxide values during frozen storage at -22°C and 92% relative humidity. They also reduced the cost of production (Hamza et al., 1987).

The rate of growth of microorganism in meat system is determined by microbial contamination, chemical properties of meat viz: moisture, pH, salt content, availability of $O_2$ (Packaging system) and storage temperature etc. Frazier (1971) stated that preservation of food for longer period require refrigeration as USDA recommended that minimal internal end point temperature is insufficient to kill bacteria and fungal spores. Anon (1979) reported that meat analogues were also an economically attractive alternative to high priced meat exhibiting colour, flavour and texture stability during processing and reported total plate counts (TPC) less than 10000 cfu/g, Coliforms less than 10cfu/g, yeast and mould- less than 10cfu/g. The *Salmonella* and *Escherichia coli* were absent. Talabi et al. (1986) reported that salting processes reduced the microbiological load of meat analogues to a level which confers product stability at ambient temperature and noted the total viable organisms/g at $37^0$C or $20^0$C were 5 x $10^{2}$ - 1.5 x $10^3$).

**RECENT TRENDS**



The effect of meat analogues on meat was dependent on price, current national legislation and consumer acceptance. Hegenbart (2002) emphasized that most food scientists did not truly understand meat analogues which along with the lack of knowledge and scarcity of individuals working on meat-analogue, the development of meat analogues and its production on commercial scale has not yet taken a concrete shape. The recent trends is the development of delicious, healthy food that are not based on meat to satisfy vegetarian section as well as nutritional security of population at large.

The sedentary life style related chronic cardiovascular health problems and environmental concerns as well as animal welfare has caused to pay more for meat alternatives (Kim et al., 2011). This has pushed the meat analogues market. UK market is considered most developed in term of production of meat analogues and increase with a 15% growth rate annually (Mintel, 2001). In the US, in 2010, the total sales of frozen meat substitutes reached 267 million USD (Salvage, 2012) as compared to 74 billion USD in beef sales (Mathews and McConnell, 2011). At present, most of the analogue products are based on soy (Tofu, Tempeh, ñTVP: textured vegetable proteinò), milk proteins, wheat proteins (ñSeitanò) or mycoprotein (ñQuornò), which all fit the criterion of efficient protein production and a beneficial carbon footprint (Hoek et al., 2004). The demand of minimally processed meat analogues is more than processed one.

**MAJOR CONSTRAINTS AND FUTURE CHALLENGES**

At present, the major constraints in the development of meat analogues is the organoleptic quality especially texture and taste of meat analogues available in the market is lower than the meat (Sadler, 2004; Mcllveen and Abraham, 1999). The major challenge in front of researchers is to develop Novel Protein Foods/ meat analogues possessing the sensory attributes of meat (Kumar et al., 2012), still the success of meat alternatives has been doubted by Hoeck et al. (2011) based on strong taxonomic factors adhering to meat as the product originating from animal. They suggested the success of meat alternative in the categorization of not meat items similar to meat by consumers fascinated by the popularizing the meat alternatives similar in appearance the processed meat products, similar usage application in meal and design of Novel Protein Food having lesser differences with meat. The price competitiveness of meat analogues is also a issue in the popularization of meat analogues.

Modern meat replacers are generally prepared by combining globular plant proteins with egg proteins, later help the retention of globular proteins at the time of frying. These are having improved conversion efficiency than meat (Aiking, 2011). World bank has also favored the development of dairy and meat analogues for sustainable developments (Goodland and Anhang, 2009). The dietary purines are present in higher amount in meat analogues and in certain soya based analogues have higher content of purines than meat. Thus the hyperurimic people and persons having risk of higher serum urates are advised to limit their use (Vojir and Petuely, 1982). This problem is taken care of by introduction of new base materials, isolated and concentrated proteins having low dietary purines content (Havlik et al., 2010).

Elzerman et al. (2011), described the main hindrance of the success of meat analogue is the recognition of meat analogues as the product that is being eaten instead of meat by consumers and thus appearance and other sensory attributes as taste, flavour, tenderness of meat substitutes should be similar to meat steak etc. Thus for success of meat analogues depends upon their incorporation in meal and recognition by consumers. The meat analogues produced from vegetable sources by incorporating texturing agents and shearing process to give fibrous texture, but the texture of the produced is reported very elastic, rubbery and hard and resulted in poor mouthfeel. These products are also possessing off-flavours originating from plants and may cause allergic reactions (Kim et al., 2011).

## CONCLUSION

Plant proteins unlike meat protein, besides providing a good source for protein are expected to reduce the intake of saturated fat and cholesterol. It also provides numerous other nutrients such as phytochemicals and fibers that are also considered desirable in the diet. Plant proteins also have some physiologically active components, such as protease inhibitors, phytosterols, saponins and isoflavones. These components have been reported to demonstrate lipid lowering effects, increase LDL-cholesterol oxidation, and have beneficial effects on lowering blood pressure. Besides, vegetarian food is digested easily than a non-vegetarian food. Thus the last few decades have seen a succession of attempts to increase the use of non-meat proteins in meat products as extenders or fillers or binder as refined wheat flour, defatted soy flour, skim milk powder etc. The marketing prospects of meat analogue is very bright due to its inherent qualities of very cheap source of protein, suitable for health conscious non-vegetarians, lactose intolerant people, persons following rules of religion, or to address ethical qualities and nutritional issues for vegetarians. Thus meat analogues have a far better chance of success than other products as some consumer desire organoleptically attractive and nutritious product entirely free of meat.

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**Table 1**: **Consumption of natural resources in production of meat**

| **Type** | **Chicken** | **beef** | **Pork** | **References** |
|---|---|---|---|---|
| Water consumption ($m^3$/ton) | 3,918 | 15,500 | - | Steinfeld et al., 2006; Hoekstra and Chapagains, 2007 |
| Grain (per kg meat) | 2 | 7 | 4 | Rosegrant et al., 1999 |
| Dry matter (per kg meat) | 3.1 | 24 | 6.2 | Alcamo, 1994 |

**Table 2**: Mineral contents in *Pleroutus* mushroom

| **Mineral** | **Quantity (mg/kg weight basis)** |
|---|---|
| Zinc | 9.31-11.18 |
| Iron | 7.94-14.80 |
| Phosphorus | 716.31-998.47 |
| Calcium | 23.66-81.16 |
| Potassium | 2225.00ï 2687.00 |
| Sodium | 750.77ï 773.67 |

Source: Caglarīrmak *et al*. (2007)

**Table 3: Common meat analogues available in market**

| **Name of product** | **Introduction/ first reported** | **Main ingredients/ origin** | **Characteristics/remarks** | **References** |
|---|---|---|---|---|
| Tofu | Japan | Pressed soya curd prepared from coagulated soya | Most widely recognized meat alternatives, blind taste, can impart flavour by smoking/ marinating | Sadler, 2004 |
| Tempeh | 1851 in Indonesia | Fermented soya based cake | Controlled fermentation of soya leads to similar shape to burger patties | William et al, 2001; Malav et al, 2013 |
| Tivall | 1997 | Soya based fibrous vegetable protein | simulate meat muscle and provide a different eating texture to other soya formats | Sadler, 2004 |
| Quoron | 1984 in EU | Mycoproteins | An altrnative of poultry & ground beef, Introduced in USA in 2002, Widely use in EU, Lower in potassium and | |

| | | | | |
|---|---|---|---|---|
| | | | equal in sodium than chicken | |
| Wheat Pro™ | 1992 | Wheat protein | Texture resembling meat by Kerry Ingredients | Sadler, 2004 |
| Arrum ™ | 1995 | Wheat and pea protein (1:1) | Resemble chunks of meat | Sadler, 2004 |
| Others- Smart Deli from mycoprotein, Seitan from wheat gluten | | | | |

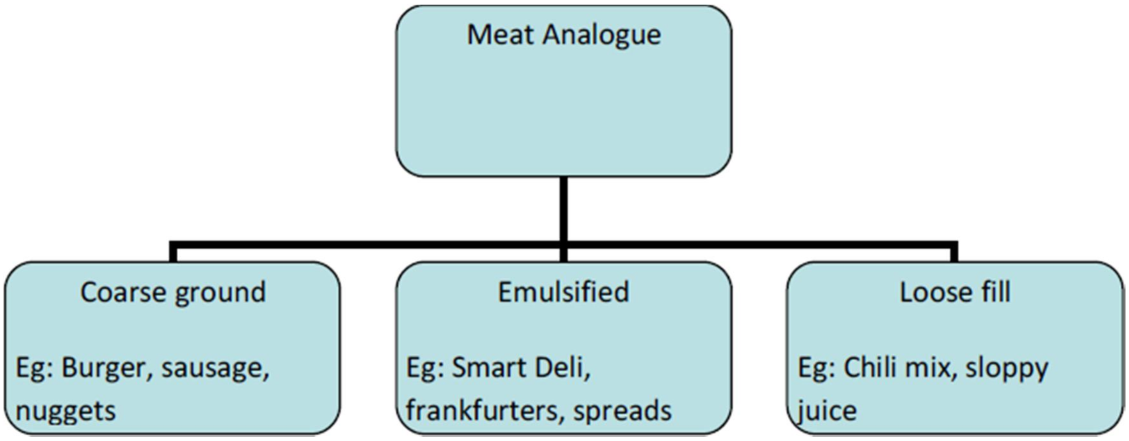


**Fig 1:** Forms of meat analogues (Sources- Malav et al., 2013; Border, 2007)

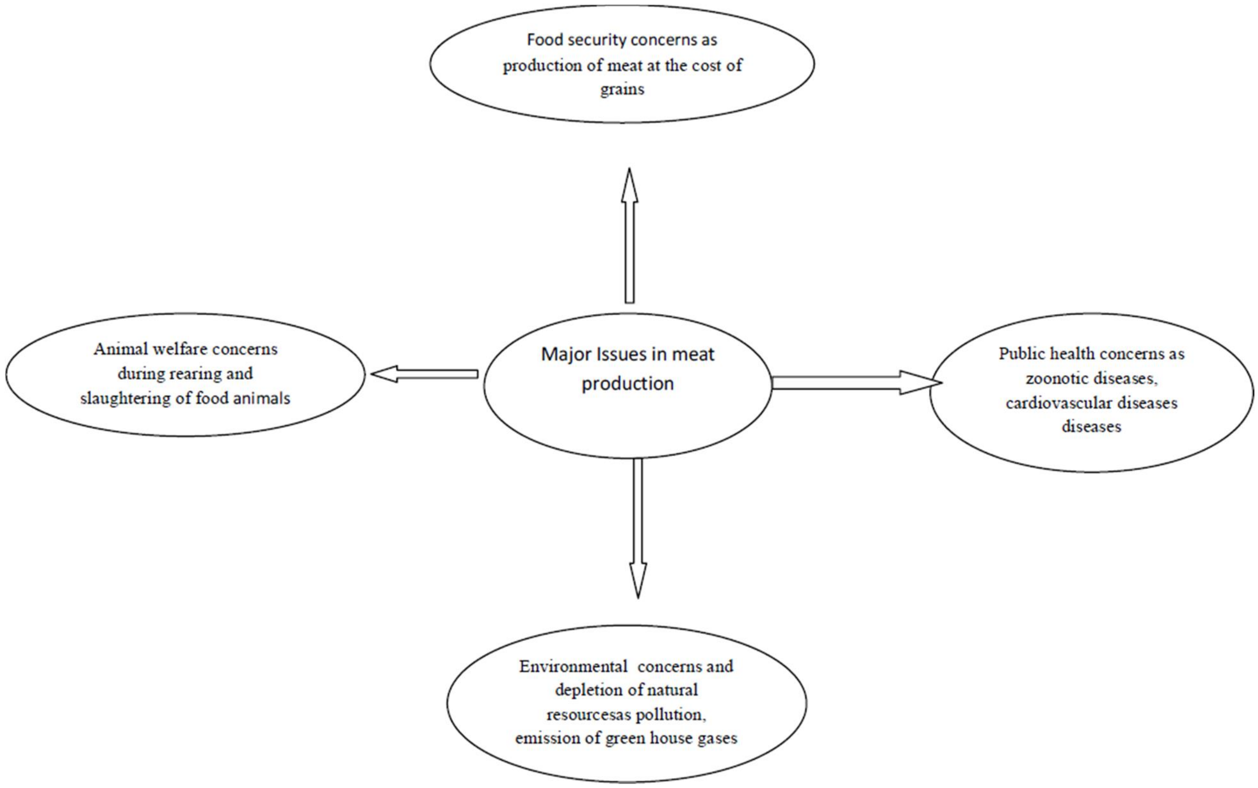


**Fig 2**: Major issues in production of meat