Technological and Health Impacts of Meat Based Functional Foods - A Review

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Abstract: ***In recent times, all round the developed world, much attention has been paid to develop meat and meat products with physiological functions to promote health conditions and prevent the risk of diseases. While developing functional foods, different technological obstacles, food legislations and above all, consumer acceptance need to be accounted for. The situation in India and other developing countries calls for more action in terms of product development as well as in legislative aspects. This review discusses the designing of functional meat products by interventions during product reformulation process and also by modifications in animal production practices. Further, this article presents a revision of studies published in recent years on the topic. Future prospects for functional meat and meat products are also discussed.***

Keywords: Functional foods, health implications, meat products, product reformulation, animal production practices

1. Introduction

About two thousand years ago, Hippocrates mentioned that "Let food be your Medicine and Medicine be your food". Since from long time a clear relationship existed between the food people ate and their nutritional health status. There is also a proverb in Ayurveda "when diet is wrong, medicine is of no use, when diet is correct medicine is of no need". Present consumers have great awareness about the nutritive value of different varieties of food and their health implications. For the last few decades, consumer demands in the field of food production have changed considerably so that more and more consumers believe that foods contribute directly to their health [1]. Nowadays food is consumed not only to satisfy the hunger of human beings, but also to prevent nutritionrelated diseases and to improve physical and mental well-being [2]

With consumer demand for healthier foods, a new term for healthier food was coined, known as Functional foods. The term „Functional foods" has various meanings in different countries. These include health foods, functional health foods, foods that are fortified with minerals and vitamins, dietary supplements and even traditional Chinese medicine products. Regardless of what name functional foods fall under, their defining attribute is their healthy function.

Nutraceutical and functional food industry is a very vibrant industry today with the claims and a clear mandate of health, wellness and prevention of diseases as one of its main goals. This concept was introduced over 20 years ago in Japan, and was followed by the implementation of a regulatory system to govern such foods. Functional foods in recent years have witnessed a tremendous increase in interest among the consumers due to their potential of providing health benefits. Since functional and health foods have shown sustainable growth in the Japanese and other Asian markets, regulations were also implemented in many countries for the production and sale of functional foods. Some countries chose to either utilize existing food and drug regulations or to develop their own systems. Others followed Codex Alimentarius guidelines or chose to adopt already established global regulations [3].

Currently there is no official, harmonized definition of the technical requirements and guidelines for functional food products in Asia. Academics and food companies generally understand that functional foods should contain or be fortified with nutrients or other bioactive compounds that help to maintain and improve health of the consumers. EC Concerted Action on Functional Food Science in Europe (FUFOSE) proposed a working definition of functional food: "A food that beneficially affects one or more target functions in the body beyond adequate nutritional effects in a way that is relevant to either an improved state of health and well-being and /or reduction of risk of disease"[4]

Functional foods maybe natural foods or foods in which a component has been added, removed or modified by technological or biological means. Other additional considerations have also been proposed to define a functional food and they are as follows [5]:

1) It is a food (not a capsule, tablet, or powder) derived from natural ingredients.
2) It can and should be consumed as part of the daily diet.
3) It has a particular function when eaten, serving to regulate a particular body process, such as enhancement of biological defense mechanisms, prevention of specific diseases, recovery from specific diseases, control of physical and mental disorders and slowing of the agingprocesses.

According to the World Health Organization and Food and Agriculture Organization,several dietary patterns along with lifestyle habits constitute major modifiable risk factors in the development of coronary heart disease, cancer, type 2 diabetes, obesity, osteoporosis and periodontal disease. In this regard, functional foods play an outstanding role.The commercial success of functional products ultimately depends on taste, appearance, price, and health claim appeal to consumers.

2. Classification of Functional Foods

Functional foods may be classified according to the potential medical benefits and properties of their ingredients. Components which provide health promoting effects in functional foods may be classified into different groups and one such classification [5] is as follows

1) Dietary fiber
2) Oligosaccharides
3) Sugar/ alcohols
4) Amino acids, peptides, and proteins
5) Glycosides
6) Vitamins
7) Choline‟s
8) Lactic acid bacteria
9) Minerals
10) Polyunsaturated fatty acids
11) Others (like phytochemicals and antioxidants).

3. Design and Development of Meat Based Functional Foods

Meat and meat products are generally recognized as highly nutritious foods that provide valuable amounts of high quality proteins containing all essential amino acids, fatty acids, vitamins, mainly B complex vitamins and especially B_{12}; minerals, mainly iron and zinc of high bioavailability and manganese and other bioactive compounds[6].Meat is highly helpful for optimal muscle growth and development. But the major disadvantage of meat is the lack of dietary fiber. Also, there are certain works related to the risk benefits concerning the red meat and processed meat consumption, mainly cardiovascular disease[7]:[8], cancer:[9]:[8], obesity[8]and type 2 diabetes[7].

Hence the strategies for the development of meat based functional foods should be to reduce the health related risk factors and to promote the health beneficial effects of meat. The first overview of the role of meat and meat products as functional foods was publishedin 2001[10]. The strategies are basically related to increasing the presence of beneficial compounds and limiting those with negative health implications in meat and meat products.These may basically affect animal production practices (Genetic and nutritional) and meat transformation systems (Reformulation process).

3.1 Animal Production Practices

Animal production practices represent the important, but a challenging opportunity to modify the presence of bioactive components. The composition of the animal tissues, and hence that of carcasses and commercial cuts varies not only according to species, but also according to breed, age, sex, feeding type etc. Animal production practices are classified into:

3.1.1Genetic Strategies

Genetic improvements to produce changes that are favorable from an economic and productive perspective and related to the production of healthy food for human diet are followed.

These include:

- Selection and interbreeding
- Using genetic markers as strategic tools for identification of loci underlying the expression of quantitative traits which include carcass characteristics, fat content and fatty acid profile[11]Biotechnological methods like cloning, transgenesis or transgenesis followed by cloning, eg, improvement of fatty acid profile by manipulating the gene with n-3 fatty acid desaturase gene[12]
- In vitro – meat production systems, like artificial/synthetic meat produced in labs. Meat produced in vitro has been proposed as a humane, safe and environmentally beneficial alternative to slaughtered animal flesh and as a source of nutritional muscle tissue[13]:[14].

3.1.2 Nutrition and feed management

This includes modifying the diet of animals to reduce or increase a particular component in its tissues. Among the bioactive compounds, lipids give more attention in the development of healthier meat products due to their health implications. For example, PUFA content in meat can be enhanced by increasing the PUFA level in the animal diet. Feeding strategies involving plant and marine sources (fish or algae) have been used to significantly increase PUFA levels in lamb, beef and pork[15]: [16]. Dietary supplementation has been used to enrich chicken, pork, beef and lamb with CLA [15].De La Torre *et al.* (2006) observed an increased CLA level in beef from cattle fed with linseed meal [17].

Since increasing unsaturated fatty acids would increase per oxidation risk in muscle foods, inhibition of oxidative deterioration could be accomplished by increasing muscle antioxidants through diet. In recent years, farm animal dietary supplementation with vitamin E has increased the concentration of this compound in animal tissue to the extent that meat became a moderate vitamin E source. Supplementation with selenium, magnesium or iron has been employed to increase the concentration of these healthy elements in meat [18].Lambs fed with concentrates having a rich source of carotenoids and fat soluble vitamins like retinol and to copherol had been observed to contain significantly higher retinol and to copherol levels in their body fat and meat products prepared from these lambs could contribute to health beneficial effects [19].

3.2. MeatProduct Reformulation Processes

Technological strategies used to design and develop functional foods based on changes in meat transformation systems are especially promising.A number of approaches can be used to remove, reduce, increase, add and/or replace different bioactive components. Modification of meat formulation process also makes it possible to use traditional ingredients and other ingredients specifically designed with certain attributes that confer health-promoting properties. Olmedilla-Alonso *et al.* (2013) has classified reformulation processes of meat as follows [18]

3.2.1Improving Fat Content

The three main goals have been identified for altering the fat content using meat reformulation strategies - reduction of total fat and energy, reduction of cholesterol and modification of fatty acid profiles [20]

Fat reduction is usually based on two main criteria, utilization of leaner meat raw materials and the reduction of fat by adding water and other ingredients like carbohydrate based fat replacers or gums or protein based fat replacers with little or no calorific content [21]: [22]

Replacement of fat already present in the meat with the health oriented fats like MUFAs and PUFAs by using naturally available in vegetable sources like olive, cottonseed, corn, soybean, peanut etc. and marine lipids had been done by many researchers [23]:[24].Lee *et al.* (2006) prepared n-3 PUFA fortified fresh turkey and pork sausages by adding an emulsion containing 25 percent algal oil into the sausage batter [25]. Marchetti *et al.* (2014) incorporated fish oil in low-fat sausage and found them to be acceptable [26]. Low-fat meat products had been formulated by using fat substitutes like konjac gel [27]: [28] agar, curdlan gum and k-carrageenan [28].Conjugated Linolenic Acid (CLA) has anti-oxidant, anti-carcinogenic, immunomodulative and anti-obesity properties and helps in regulating bone metabolism and reduces the risk of diabetes [29]. It is naturally present in ruminant milk and flesh, especially in grass fed ruminants. Commercially produced CLA isomers have been injected into whole muscles [30]and incorporated into meat products such as sausages[31] to achieve enough levels of CLA to produce health benefits when consumed in smaller portions.

3.2.2.Incorporation of Plant Proteins

Plant proteins have been used in meat products for technological purposes,to reduce costs, for nutritional reasons and recently for health promoting properties. Some of the proteins from plant sources like sunflower,walnut etc. have been used in meat systems to balance lysine /arginine ratios and have healthy, beneficial effects [32].Soy protein has been used as functional ingredients in various FOSHU (Foods of Specific Health Use) meat products (such as low fat sausage). Protein derivatives of vegetable origin like soy and sunflower proteins have been described as useful in the prevention and treatment of cardiovascular diseases, cancer, osteoporosis and in the relief of menopausal symptoms [33]. Serdaroglu *et al.* (2005) replaced meat protein with blackeye bean, chickpea and lentil at the level of 10 percentage in meatballs and observed them to be acceptable [34].

3.2.3.Incorporation of Probiotics

Because of their health benefits probiotics could promote, market for the meat industry. Meat products, processed by fermentation without heating have been considered an excellent vehicle for probiotics. Lactic acid bacteria (LAB) are essential agents during meat fermentation improving hygienic and sensory qualities of the final product. Their fermentative metabolism prevents the development of spoilage and pathogenic micro flora by acidification of the product and also helps in color stabilization and texture improvement.Peptides generated during fermentation process also act as sensorial and hygienic biomarkers.

Enterococcus faecium PCD71 and *Lactobacillus fermentum* ACA-DC179 were applied as protective cultures in chicken meat against *L. monocytogenes* and *S. enteritidis*respectively, and it was observed that they significantly reduced growth of the pathogenic bacteria [35].

Fadda*et al.* (2010)observed that fermentation of meat by LAB was a specific and complex process where LAB acted as starter culture and improved the sensorial quality and also acted as a bio preservative agent [36]. Bacterocinogenic LAB and theirbacteriocins produced a low molecular weight peptide from protein hydrolysis in fermented products like dry fermented sausages.

Jahereis *etal*. (2002)found out that*Lactobacillus paraceasei* LTH 2579 incorporated into sausages modulated host immunity. The probiotic bacteria resulted in a significantly higher titer of antibodies against oxidized LDLafter 5 weeks of consumption of probiotic sausages [37].

3.2.4Incorporation of prebiotics and dietary fiber

Different prebiotics and dietary fibers have been used in the manufacture of meat products for their technological qualities as non-calorific bulking agents, to improve water and oil retention or emulsion stability, to modify the texture, to help overcome the effects produced by composition changes etc. They also have physiological properties like reducing diabetes risk, favoring blood lipid regulation, reducing serum cholesterol level, preventing cardiovascular diseases (CVD), colon cancer and constipation and regulating intestinal transit. The insoluble fraction of the fiber (IF) is related to intestinal regulation, whereas the soluble fiber (SF) is associated with a decrease of cholesterol levels and the absorption of intestinal glucose. Orange, apple, peach, olive, vegetable oat bran etc. are rich sources of dietary fiber. [38].

Currently, there is a tremendous increase in the studies regarding the incorporation of different concentration of prebiotics like inulin, dietary fibre and fibre rich ingredients from cereals like oats, rice, wheat etc.; fruits like apple, lemon, orange, etc.; legumes like soy, peas etc.; roots like carrot, sugar beet, konjac etc., tubers like potato and seaweeds like red and brown algae in the formulation of fresh, cooked and fermented meat products.[39] : [40].

3.2.5 Enrichment with Minerals

Now a days there is an increased trend of enrichment of meat products with some of the essential minerals like selenium, calcium, zinc etc, even though meat contain minerals like iron and has meat factor characteristics. According to Soto *et al.* (2013),calcium citrate, malate and lactate could be used as functional ingredients in meat products like hamburger and bologna sausages to enhance the calcium levels, so that the percentage of calcium availability and transportation through cell membrane when these products were consumed were similar as when milk was consumed[41]. García-Iñiguez*et al.* (2010)observed that meat products like dry fermented sausages enriched with selenium, yeast and iodized salt had nutritional and health beneficial effects[42]. Consumption of about 50g of this product would satisfy full dietary recommended intake of selenium and seventy per cent of iodine. Not only minerals as such, but some non-meat ingredients like walnut, seaweed etc. are added to processed meat to increase the levels of minerals like copper, magnesium, manganese and potassium [32].

3.2.6 Incorporation of Vitamins and Antioxidants

Meat is an excellent source of vitamins but it is deficient in certain vitamins like vitamin C and also has lower levels of vitamin E. Hence to improve the vitamin status of meat, vitamins can be added in the formulation of meat products either in the form of commercial preparations (isolate) or as components of non-meat ingredients like walnut, wheat, honey, citrus by products etc. [32]Jimenez-Colmenero *etal.* (2010)used vitamin E as an ingredient in the frankfurter product formulation[32]. Vitamin C incorporation in beef patties and cooked and dry cured sausages had been tried by [43] Fernandez-Lopez *et al.* (2004) and Sanchez – Escalante*et al.* (2001) [44]. Gadekar *et al.* (2014)fortified restructured goat meat product by addition of sodium as corbate and tocopherol acetate [45].Fortified chicken meat nuggets with ground carrot and sweet potato had been developed by Biswas *et al.* (2011) [46]and they observed that the fortified meat nuggets had significantly higher levels of beta carotene when compared to control. Carotenoids have been used in meat products, because of their anti-oxidant, anti-inflammatory and anti-cancer activities.

Pulp, dried peel or juice of tomato, rich in lycopene had been used in different meat products. Calvo*et al.* (2008)added dry tomato peel to meat batter during the preparation of fermented sausage at different concentrations and observed that after 21 days ripening, a significant level of lycopene was present in the sausage [47].Anti-oxidant activity of hydroxyl tyrosol had been demonstrated in frankfurters enriched with n-3 PUFA by addition of individual plant (olive, high-oleic-acid sunflower, cottonseed, soya, etc.) or marine (fish, algae) oils[48] : [49. Also, anti-oxidant properties of L-carnitine and carnosine in meat products had been studied byDjenane*et al.* (2004)[50].

3.2.7. Other added compounds /ingredients

Apart from above compounds, some other ingredients incorporated in to meat for healthbenefits are,sterols,taurine etc. These are incorporated into products either as purified compound or as non-meat ingredient like walnut, soybean, seaweed, carrot, and herbs which contain these compounds [18].

Bioactive peptides have been identified from different food stuffs including milk and meat and these peptides have antihypertensive, opioid, anti-oxidant and anti-thrombotic properties [51]. Castellano*etal.* (2013)observed that anti-hypertensive bioactive peptide (ACE inhibitory peptide) generated from porcine muscle protein by the action of lactic acid bacteria could be incorporated in preparing healthier functional meat products [52].

3.2.8 Reduction of Unhealthy Exogenous Components

Minimizing the unhealthy exogenous components is one of the important aspects to be considered while designing the functional meat products. This may prevent or reduce the negative effects on human health. Some of these components are sodium, phosphate, nitrite, allergens etc.[53] :[54].According toHsu *et al.* (2009)high dietary intake of cured meat products increased the risk of gastro intestinal cancers due to the in vivo formation of carcinogenic chemicals [55]. Reducing the level of nitrite or replacing nitrite with some other compound in cured meat products had been tried. Increased intake of sodium has been found to increase the incidences of hypertension and hence low sodium food products are gaining importance among health conscious people. Different low sodium meat products have been formulated by replacing a part of sodium chloride by other safe compounds which mimic the effects of sodium chloride. Ruusunen *et al.* (2002)had prepared reduced salt bologna and cooked hams by adding phosphates [56].

To prevent the development of disease, an understanding of how nutrients act at the molecular level is needed. This involves a multitude of nutrient-related interactions at the gene, protein and metabolic levels. As a result, nutrition research related to genetics is now given priority and this area is called nutrigenomics [57]. Nutrigenomics means personalized nutrition to an individual according to his genetic makeup. Specific functional ingredients may be incorporated into foods that can improve the health of consumers of different genetic makeup. Also, researches are to be carried out towards substantiating the functional effects of healthy meat products in man so that the availability of bioactive components in functional foods can be assessed.

4. Conclusion

In our country, although there are a few functional products especially of milk and egg, available in the market, meat based functional products are still in the research stage only. Efforts are to be taken to standardize and market functional meat products especially traditional meat products containing bioactive compounds. There had been several laws and regulations covering the foods market in India. However, there had been no single law that significantly regulated the functional foods in market even in the recent past. Now, a new set of regulations namely Food Safety and Standards (Food or Health Supplements, Nutraceuticals, Foods for Special Dietary Uses, Foods for Special Medical purpose, Functional Foods, and Novel Food) Regulations, 2015 is under process which may help to integrate and stream line themany regulations covering the nutraceuticals, foods and dietary supplements.

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