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Development of Meat-based Functional Foods: A Review

Alim-Un-Nisa*, Naseem Zahra, Sajila Hina,Shahid Masood, Ali Javed, Syed ManzarInam

Food and Biotechnology Research Centre, PCSIR, Laboratories Complex, Ferozepur Road, Lahore-54600, Pakistan.

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ABSTRACT

Meat products can be made healthier by optimizing the concentrations of bioactive compounds present in meat e.g. CLA, L-Carnitine etc. Different strategies for modifying the concentration of healthy compounds in meat to produce safe and healthier functional food products are discussed in the review. These strategies include meat production, handling, storage and utilization processes. The assessment of these functional food products is necessary to measure the functional capacity of these foods. Research in the field of intervention studies on functional variability of modified meat products in humans have also been discussed.

1. INTRODUCTION

Increasing awareness about the effect of diet and specific food ingredients on health has initiated studies on the impact of food components on health. Consumers are now more concerned about the health issues and demand more nutritious food products with increased health promoting factors. Functional foods are the foods which affect the body systems in a better way by providing nutrition more than required in a manner to improve health and prevention from diseases. These are categorized as functional on the basis of their impact on health hence both unmodified and modified foods (by technological or biotechnological means) are included in the class of functional foods [1]. In recent years, many studies have been conducted on tertiary functions of foods [2-6]. Tertiary functions are the functions of food components which control physiological systems to reduce chances of diseases. Anticarcinogenecity, antimutagenecity, antioxidative activity and antiaging activity are examples of such functions. There is an increase in the production of such functional foods on large scale due to growing awareness about effects of diet for a healthy living. For example, dairy products with increased probiotics are being studied [7]. Meat is a major source of food proteins and also of some valuable nutrients like minerals and vitamins [8-10]. Nutrients like iron, vitamin B12 and folic acid have inferior bioavailability in food other than meat. However, there are increased health concerns due to relationship of some meat constituents with major chronic diseases [11-13]. Food manufacturers are now in pressure to produce healthier meat products. Functional food provide an incomparable opportunity for meat industry to provide meat products with enhanced health promoting factors and reduced disease causing components. Through different techniques, meat can be processed to produce a large variety of products with health beneficial properties [14, 15]. In designing healthier meat products, all steps from animal processing to product processing are taken into consideration. In this article, focus is kept on food processing. There are different feasible methods for producing meat products with health benefits. Strategies suggested by Jimenez *et al*. [16] include selection of raw materials, variation and designing new formulations of meat products which have improved nutritional profile.

2. MEAT BASED BIOACTIVE COMPOUNDS

Natural compounds present in foods or in extracted condition which enhance physiological performance of human body by preventing or treating diseases are known as nutraceuticals [17, 18]. There are several bioactive substances (nutraceuticals) which are meat based. These include creatine, conjugated linoleic acid, L-carnitine, carnosine, glutathione, anserine and taurine. Studies reveal that modifying animal feed can increase the content of bioactive compounds in the meat [19, 20].

* *Corresponding Author*
Alim-un-Nisa, Food and Biotechnology Research Centre, PCSIR, Laboratories Complex, Ferozepur Road, Lahore-54600, Pakistan.
Email: nisaalim64 @ yahoo.com, Tel: +92 42 99230688

2.1 Conjugated linoleic acid

Conjugated linoleic acid was first discovered in extracts of grilled beef as an anticarcinogenic compound. These are basically different isomeric form of octadecadienoic acid [21-23]. CLA mostly constitute ruminant'sfat compositions whereby formed by conversion of linoleic acid by rumen bacteria. In a ruminant animal, after its absorption, CLA is transported to mammary tissue and muscle. Content of CLA in beef fat is 3-8 mg per gram of fat. Factors like breed, age and feed composition affect content of CLA in meat [24]. Heating processes like cooking also increase the levels of CLA in foods [25]. In fermented milk products, CLA formation is enhanced by probiotic bacteria [26]. Octadeca-*c*9, *t*-11-dienoic acid is the most commonly found isomer of CLA. Scientists are taking much interest in studying this fatty acid due to its anticarcinogenic property. According to some recent studies on diseases, chances of colorectal cancer can be lowered through intake of CLA and high-fat dairy foods [27]. CLA has also been identified as antioxidative and immunomodulative agent. CLA may also have properties like obesity control, control of bone metabolism and reduction of diabetes risks[28].

2.2 Histidyl dipeptides

Fruits and vegetables have some antioxidant compounds which help to defend the body against free radicals [29]. These antioxidants actually reduce the production of free radicals in body [30]. Common food derived antioxidants are Ascorbic acid, Vitamin E, β carotene and poly-phenolic compounds. These compounds are known to lower down the risks of cancer and other diseases. Carotenoids, glutathione, ascorbic acid, tocopherols, lipoic acid, ubiquinone, spermine are also derivedinternally as antioxidants in skeletal muscles [31].

In meat, two histidyl dipeptides named as carnosine (β-alanyl-L-histidine) and anserine (N-β-alanyl-1-methyl-L-histidine) are most commonly found with potent antioxidant property. Carnosine concentration in chicken meat is found to be 500 mg/kg whereas anserine content is more than carnosine. These compounds are able to chelate transition metals like copper [32]. Studies have reported these antioxidants as a defense against many diseases and oxidative stress related conditions [33,34]. Recent experiments have reported the bioavailability of carnosine in human plasma after beef intake [35].

2.3 L-Carnitine

Human body produces L-carnitine (β-hydroxy-γ-trimethyl amino butyric acid) mainly in kidneys and liver [36]. It is involved in the transport of long chain fatty acids through inner membranes of mitochondria to help in oxidation process resulting in energy production. In muscles, L-carnitine helps in energy production when body is in state of hard exercise. It is found in skeletal muscles of various animals. Concentration of L-carnitinein in beef has found to be 1300 mg per kg of thigh [37]. L-carnitine has also been found to lower the cholesterol level of our body [38]. Calcium absorbing property of L-carnitine improves skeletal strength and it helps body to build lean muscle mass by chromium picolinate absorption. A recent study showed that apoptosis was retarded by L-carnitine and skeletal muscle myopathy in heart failure was prevented by it. Beverage with added L-carnitine is available in the market claimed to be good for recovery of energy and help to combat tiredness. Another product made from a by-product of corned beef has been marketed in Japan which contains L-carnitine and carnosine as functional food ingredients [39].

3. STRATEGIES FOR DESIGNING MEAT BASED FUNCTIONAL FOODS

Several reviews have been written to discuss strategies and techniques for designing healthier meat products [40-46]. These strategies aim for increasing the content of healthier components and reducing the content of harmful components from meat. Both farming of animals and variation in the meat formulations can be included in these strategies. The conditions of meat storage and consumption form are also considered as they also effect the composition of meat. In the following sections, feasible techniques and methods to control concentrations of healthy meat components will be discussed.

3.1 Animal Production Practices

The availability of bioactive compounds in meat can be modified through animal production practices. The composition of animal tissue and that of carcasses vary according to type of animals and the other characteristics. In-vivo modification approaches are present to modify fatty acid, minerals and vitamin profile and composition. These compounds have a demonstrated efficacy as bioactive compounds and are easy to modify in the tissues [44].

3.2 Feeding management and Nutrition

Lipids are the bioactive compounds that have gained much importance in designing meat based functional foods due to their effect on health. In animal tissues, lipids can be deposited either by endogenous process i.e. denovo system or by exogenous methods (supplied by feed). Several feeding trials have been done on animals to increase the content of mono (MUFA) and poly-unsaturated (PUFA) fatty acids in animal tissues. By increasing MUFA's in animal feed, the content of MUFA in the meat can be upgraded. Some studies showed that PUFA's in animal meat can be enhanced by adding different PUFA rich ingredients of plant and marine origin [47-49]. The level of CLA in chicken beef and lamb have been augmented by dietary supplementation [47, 50, 51]. Studies have shown that in poultry, the content of cholesterol can be reduced selectively in muscle tissue of living animal by raising the copper level in feed [52]. Also production practices for reducing fat content in farm animals have also been discussed in many reviews [53-55].

Peroxidation risk in muscle food may increase due to unsaturated fatty acids and cause oxidative damage. This can be prevented by enhancing the muscle antioxidants through animal diet. Recent studies have indicated that when vitamin E was added as a supplement in animal diet, its concentration in animal tissue increased. Mineral contents like Fe, Mg and Se of meat can also be increased by dietary supplementation with these healthy elements.

3.3 Selection and Interbreeding Practices

In recent decades, management and selective breeding practices have been utilized to cut down fat content of carcass [56].

3.4 Genetic Information

Researchers are now able to modify composition of carcasses through genetic improvement selection programs. Fat content and fatty acid profile of carcass can be manipulated by identifying the specific loci which express the quantitative traits, with the help of genetic markers [56].

3.5 Genetic Manipulation

Biotechnological practices like cloning and trans-genesis are very effective scientific strategies. It involves direct manipulation of genes to enhance quality safety and yield of food products [57]. Fatty acid profile can be easily modified using this strategy. In an experiment, n-3 fatty acid desaturase gene (which is lacked by livestock) was made to express in transgenic animals to produce high levels of PUFA's [58, 59].

3.6 Reformulation of meat products

Development of meat based functional foods by modification in transformation systems of meat is an effective scientific strategy. Content of different bioactive compounds can be altered using several techniques. Meat formulation process allows the use of traditional ingredients and other ingredients to make meat products healthier.

3.7 Modifying fat content

Utilizing strategies for meat reformulation, fat content can be improved by modifying fatty acid profile, reducing fat and cholesterol contents. Water and other fat replacers (gums, protein based or carbohydrate based) can be added to reduce the fat density. To design meat products with reduced fat, leaner meat is used as raw material. Manufacturing and preparation procedures are very important in meat reformulation strategies [60-62]. Fatty acid composition of meat is very important in making healthier products because plasma lipids are differently affected by each fatty acid. Strategies are present to alter the fatty acid profile of meat by replacing unhealthy fats with healthy ones. Healthy fats have smaller proportions of SFA's and larger proportions of unsaturated fatty acids and also low cholesterol values. Lipids either from plant origin or from marine sources can be incorporated directly as liquid oils into meat products or by incorporation in encapsulated and emulsified forms (simple and multiple emulsions). Plant sources for lipids include maize, soy, bean, olive, peanut and cottonseed etc. and marine sources are mainly algae and fish. Use of fat other than from animal origin has been discussed in many reviews [63]. Successful experiments to inject commercially produced CLA isomers in meat have been conducted [64].

It has also been incorporated into meat products such as pate [65] or sausage [66] to make these products healthier. Physiochemical procedures have been utilized for removal of cholesterol from meat raw materials [52]. In recent years, different strategies of cholesterol removal have been devised including fermentation of meat products by using bacteria [67] and using fat diluting techniques in meat raw materials [52].

3.8 Adding Plant Proteins

For past 3 to 4 years, there is an increased trend in using plant proteins in meat products because of their health enhancing properties and low cost. Plant proteins cut down cholesterol and energy levels and increase content of health promoting proteins and thus upgrade nutritional value of meat products. Studies depict that increasing plant proteins from sources like sunflower, walnut etc. in meat can balance lysine/arginine ratio and thus can make meat more beneficial. Several meat products have been designed to maintain blood cholesterol level by using soy protein as functional ingredient [14, 65].

3.9 Probiotic Meat Products

Probiotics can be efficiently ingested through fermented meat products which are processed without heating. There are many published studies which show the incorporation of probiotic bacteria (Lactobacillus acidophilus, Lactobacillus casei, Lactobacillus rhamnosus, Lactobacillus paracasei, Lactobacillus plantarum, etc.) to fermented sausages [14]. Probiotic strains are not damaged by various technical treatments during manufacturing process and also not in the gastrointestinal tract. Functional fermented meat products containing lactic acid bacteria of human gut are now being marketed [40, 60]. Reviews on probiotics in fermented meat products are available [40, 68-71].

3.10 Addition of Fiber and Prebiotics Contents

Owing to physiological and medicinal properties, prebiotics and dietary fibers are used as important functional ingredients in meat products. Development of meat products using varying quantities of fibers and prebiotics is increasing. Many Fruits, vegetables, legumes, cereals and sea weeds are good sources of these compounds. Published reviews are present on use of dietary fibers as efficient functional ingredients to develop fiber enriched meat products [72, 73].

3.11 Mineral enrichment

Many beneficial minerals (Fe, Se, Ca, Zn etc) are present in meats. Different techniques have been devised to modify the concentration of these minerals. Meat products enriched with selenium [74], Calcium [75] and iron [76] have been produced. Studies shows that non meat ingredients (walnut, sea weed etc) can also raise the mineral content of processed meat [15, 77]. Dry fermented sausage was enriched with iodine in a study [74].

3.12 Incorporation of Vitamins and other Antioxidants

Although meats are sources of other vitamins, strategies have been employed to incorporate vitamins in meat to produce healthier products [14]. These compounds have been used in product formulation either in isolated form or may be added from some other sources like honey, walnut, wheat grain etc. Different functional meat products like vitamin E enriched Frankfurters [15], Vitamin C enriched Beef patties [78, 79] and sausages fortified with folic acid have been produced at commercial level [80].

Carotenoids are also being used in foods because of their anti-cancer, anti-oxidant and anti-inflammatory properties. For example, lycopene from tomato [81,82] and lutein [83-85], carrot and sweet potato rich in provitamin A [86] and spinach rich in lutein and zeaxanthin [87]. Extracts of fruits (grape, liquorice root, horsetail, arbutus berries, etc.) [88,89], spices(cardamom, clove, nutmeg etc)and herbs for example oregano, rosemary, melissa, green tea, etc[46,79,90] have also been used as a source of natural antioxidants. Frankfurters enriched with n-3 PUFA contain hydroxytyrosol which has antioxidant property [77, 91].

3.13 Removal of unhealthy exogenous compounds

Different techniques and methods have been employed to reduce the content of different unhealthy exogenous compounds like sodium, phosphate, nitrite or allergens including gluten, lactose etc. During meat processing these compounds are added as ingredients and additives [44]. Sodium intake can be controlled by adopting strategies to lessen salt contents. These strategies involve first to select raw materials of meat, varying manufacturing methodologies, replacement of salt substances, enriching flavor and modification of physical form of salt [92, 93].

Control of phosphate content in meat products is also very important because dietary inorganic phosphate has been found to increase risk of lung cancer [94]. Also excessive phosphate in diet can disturb the calcium, iron and magnesium balance in body which is a threat of bone diseases [95]. Meat products processed without phosphate additives have been sold in market [14]. Chemicals like methemoglobinemia and nitrosamines are formed from dietary nitrite. These chemicals are considered to be carcinogenic and teratogenic activities.

Technological methods to reduce the use of nitrite in meat processing have been devised. Also, strategies to prevent damage due to nitrosylation reactions have been proposed [96]. Use of ingredients with high nitrite content in meat processing has been discouraged [45]. Allergen free meat products have also been produced by utilizing allergen free non-meat ingredients during meat product formulation [40].

3.14 Strategies to be adopted during processing and storage

Every step in the production of meat functional foods directly correlate with the quality of product as well as to maintain the quality and composition of those products formulated earlier.[44].Any alterations in these steps may enhance the quality of these products or in some cases also incorporate injurious compounds such as different amines, poly aromatic hydrocarbons, nitrosamines etc. Presence of these compounds make meat products harmful for consumption as they are involved to provoke cancer like diseases. All the possible implications such as compositional variation, temperature and time to cook these products can be adopted to avoid the formation of these undesirable compounds [96-98]. Bioavailability of some important compounds like creatine, coenzymeQ10, taurine may also greatly affected by processing and storage conditions of these products [44].

4. FUNCTIONAL EVALUATION OF MEAT FUNCTIONAL FOODS IN HUMANS

Many studies are available regarding strategies for optimization of bioactive ingredients in the meat based functional foods but still there is lake of in vitro studies to confirm that how much these supplementary compounds are bioavailable [99-102] especially even there is scarce information about assessment of the functionalization of these products in the humans who are ultimate end users. Evaluation of the efficacy of such functional foods is proved only from evidence base data of human studies, use of validated methods, assessment of the characteristic of food ingredients and the biological end points [103,104].

Meat based functional foods are mainly assessed for their probable positive role in lowering the risk of cardiovascular diseases as mostly meat is considered as one of the major cause of this health issue [105]. Moreover, LDL-cholesterol and plasma are also used as biological markers for routine analysis to monitor cardiovascular diseases. In addition these products are also analyzed for the any interventions made by the use of biomarkers.

5. CONCLUSION

Nutrition plays a major role in development of a good health and prevention of diseases. Meat and meat products are considered to be the best foods for delivering bioactive compounds because the meat is frequently consumed and has a good nutritional value which can be modified easily according to specific needs. Many strategies have been devised to develop healthier meat products. The producers of these meat based functional foods claim that these products have such bioactive compounds in optimized concentration which can promote health and decrease disease risk factors. However, there are fewer studies to evaluate the effect of these compounds on health. We need more advancement in the field of human intervention studies. Moreover, we have to define all the diet based markers which would be helpful to detect disease risk factors.

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