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Review Paper

Strategies to Develop Healthier Meat and Meat Products

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ABSTRACT

The extensive use of chemical preservatives in food processing industry and their association with health related problems has increased the demand for development of products which are safe, natural and contain fewer food additives. The current strategies in development of healthier meat and meat products are through genetic improvement, nutritional manipulation, feeding management practices, reformulation of meat products including use of natural antioxidants and antimicrobials from plant extracts and their essential oils, enzymes, peptides, bacteriocins, bacteriophages and fermented ingredients. These strategies actually lead to development of healthier meat and meat products with the concurrent improvement of functional compounds. Antioxidant and /antimicrobial activities of some spices, herbs and other plant extracts and/or their essential oils are mainly due to the presence of some bioactive compounds like phenolics, flavonoids, aldehydes and terpenes. Reduction of some specific unhealthy compounds like cholesterol, fat, sodium, nitrites and even lowering of calorie content are other strategies to develop healthier meat and meat products. Functional compounds, especially antihypertentive peptides, opioid peptides, antioxidative peptides can also be generated from meat and meat products during processing such as fermentation, curing and aging. The use of these ingredients in meat products offers processors the opportunity to improve the nutritional and health benifits of their products. An overview of the research works done on the development of healthier meat and meat products adopting different strategies is presented in this review.

Keywords : *Designer meat, Functional meat products, Natural antioxidants, Bio-active compounds, Health foods.*

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Meat we eat is an integral part of human diet. In general, all meat and meat products have wider acceptability by the consumers because of good nutritional profiles. But, they have also some negative nutritional influence which may affect the eating quality. Consumers want the foods they eat not only taste better but also retain their natural flavour, colour, texture and also be healthy. So, the future belongs to new products and new processes with the goal of enhancing product performance, quality and safety. Indeed, a reliable and consistent access of safe, fresh, natural, nutritious, flavorful and healthier meat products needs to be explored as a priority throughout the world. There are diverse possible strategies for developing healthier meat products (Lai *et al.* 2006; Naveena *et al*. 2008a, b; Datar *et al.* 2010; Olmedilla-Alonso 2013; Biswas *et al.* 2011a; Biswas *et al.* 2011b; Biswas *et al.* 2015). As in other foods, in order to achieve healthier meat and meat products, it is necessary to avoid undesired substances which may be natural or reduce them to appropriate limits, and to increase the levels of other substances with beneficial properties. Essentially, three kinds of strategies are used to achieve this goal- (1) by modification of carcass composition through changing animal production strategies (2) manipulation of meat raw materials through effective handling and processing of raw produce (3) and the reformulation of meat products (Jimenez-Colmenero 2001).

The inclusion of functional compounds like omega-3 fatty acid, vitamin E, conjugated linolenic acid, selenium, herbs, spices, pre-and probiotics, phyto-chemicals, bio-active peptides etc in animal feed or their direct addition in product formulation could essentially influence consumer's health. In a study, it has been reported that poultry meat enriched with ω-3 fatty acids could meet 70-130% of the recommended daily intake for humans. Some studies have shown that conjugated linoleic acids (CLA) can reduce the risk of certain cancer problems as well as associated cardiovascular diseases. Selenium and vitamin E have been shown to reduce the risk of prostate and colon cancer, while carotenoids may reduce breast cancer risk. Extensive evidence also showed that foods rich in ω-3 polyunsaturated fatty acids are associated with reduced risk for all-cause mortality, coronary heart disease

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and stroke. This literature review will provide an overview on strategies for functional improvement of meat and meat products that can be realized by adding natural bioactive compounds in feeds/foods or reduction and elimination of some unwanted compounds that are important for health.

Modification of meat quality through production strategies

Meat carcass composition can be altered at the stage of animal production itself. The composition of the carcass and commercial cuts varies not only according to species, but also according to breed, age, sex, feed type, etc. A wide range of strategies is available for inducing changes in different meat constituents such as protein, lipid content, fatty acid composition, vitamin E level, etc. These include genetic selection, nutrition and feeding management, growth-promoting and nutrient partitioning agents, immunization of animals against target circulation hormones or releasing factors and gene manipulation techniques (Hay and Preston

Genetic selection: Genetics play a crucial role in the development of farm animals and thus on the quality and nutritional profile of meat obtained from them. By selecting races and genetic lines, carcass composition has been significantly altered. Some of the researches were also focused on the production of more tender meat (Solomon *et al.* 2002). This has led to a substantial reduction in fattiness and a higher percentage of unsaturated fatty acids (Morrissey *et al*. 1998). It has been noted that leaner carcasses are generally associated with a more glycolytic muscle fibre type and hence more rapid postmortem metabolism, pale meat colour and lower water holding capacity. Some changes in lipids have been further reported to be dependent on sire genetic type (Armero *et al.* 2002). However, the meat from an aged animal may have a stronger flavour and colour but it correlates directly with increased intramuscular fat content and connective tissue which is a consequence of the action of muscle proteolytic and lypolytic enzymes, which are affected by age. Muscles from heavy pigs have been reported to have a higher peptidase to proteinase ratio and higher lipase activity than muscles from younger pigs (Rosell and Toldra 1998). Meat from barrows has more fat, marbling and a thicker layer of subcutaneous fat than meat from gilts as sex has an influence on the fat content of the carcass.

Manipulation of feeding and nutrition: Since last few decades there has been a good deal of research on altering the fatty acid composition of the meat to attain the levels recommended by the nutritionists (Enser *et al.* 1998, Wood *et al.* 2003). However, manipulation of fats to improve the content of PUFA may cause certain problems like oxidation of fat, generation of off-flavours, colour fading and defects on sensory quality or undesirable health effects (Toldra *et al.* 2000). Further, it may be mentioned that the amount of feed also affects the fat content in meat. An excess feed may increase the amount of intramuscular fat while feed deprivation may reduce the fat especially in glycolytic muscles by inducing lypolysis (Fernandez *et al.* 1995). It has been reported that the ratio of fat to lean in pig and cattle carcasses is affected by the diet composition and feeding levels, particularly the energy and protein intake. In pigs, restricting the energy intake will reduce carcass fat, and feeding excess protein will result in a higher proportion of lean to fat (Hay and Preston 1994). Dietary fatty acid composition is an extremely important part of the fatty acid profiles of monogastrics and is less important in ruminants where desirable combinations of fatty acids are to be obtained for human consumption with less saturated and more mono and polyunsaturated fatty acids (Byers *et al*. 1993). However, there are several ways of minimising lipid oxidation and some of them are associated with animal feeding (Morrissey *et al*. 1998). It has been reported that vitamin E-supplemented diet in poultry, pigs and cattle prolongs the shelf-life of these products. The antioxidant activity reduces rancidity and helps the meat retain its colour (Pszczola 1998). Feeding strategies have been successfully used to produce eggs, beef and chicken with up to 20 times the normal level of DHA (docosahexaenoic acid, 22:6 n-3), 7 times the normal level of vitamin E and 6 times the normal omega-3 content of their traditional counterparts (Sloan 2000). By using repartitioning agents like anabolisers, growth hormones, etc., or immunization strategies, it is possible to alter those metabolic processes that regulate the use of nutrients during growth, thus promoting protein synthesis and reducing fat deposition (Byers *et al*. 1993). For example, the administration of somatotropin to pigs can lead to a 60% reduction in carcass fat, a 70% increase in carcass protein content and 27% less lipid content in lean tissues containing as much as 40 and 37% less of SFAs and MUFAs, respectively, and no differences in PUFAs (Solomon 1994). Strategies for reducing carcass fat content include elimination of castration, level of maturity (Bass *et al*. 1990).

Changes in fatty acid profiles: Since in large animal species unsaturated fatty acids are subjected to biohydrogenation in the rumen, so greater opportunities exist for production of ω-3 fatty acids enriched meat from non-ruminants, in particularly, from animals such as pigs, poultry and fish. Feed containing fish oil, flax seeds including linseed, millets and sea algae are best source for producing omega-3 fatty acids enriched meat. Many papers have been published on increasing the unsaturated fatty acids composition of pigs and poultry (Lopez-Ferrer *et al.* 2001, Mc Clements and Decker 2008, Bou *et al.* 2009). This is already practiced in specialty products such as Iberian hams which are high in oleic acid due to consumption of acorns and aquaculture salmon which are fed fish oils high in omega-3 fatty acids (Blanchet *et al.* 2005). According to some researchers, feeding flaxseed for 24 days before processing produced optimal breast meat ω-3 enrichment, carcass weight and meat yield in broilers. However, the best ω-6/ω-3 from human health aspect was detected by the linseed oil and cod liver oil supplementation. The effect of feeding fish oil, linseed oil, sunflower oil and soybean oil and different oil levels on fatty acid composition, long chain ω-3 PUFA, ω-6/ω-3 ratio and oxidation stability as malonaldhyde (MDA/kg) contents of Cobb broiler chicken muscles were studied. It was shown that dietary fat source influence lipid composition of thigh meat more than dietary fat level. Thigh meat from broiler groups fed with 8% oil showed a difference in fatty acid profile to the other oil levels (2-4%). Broilers fed with fish oil had statistically higher EPA and DHA levels in thigh meat than broilers fed with soybean oil. But use of fish oil and vegetable oil rich in long chain unsaturated fatty acids in broiler diets may result in an increased fatty acid oxidation in muscle tissues. Similarly, the oleic acid content in feed containing the high oil, high oleic corn was reflected on the composition of breast meat and skins of Peking ducks.

While for lambs raised on pasture feeding usually present more ω-3 fatty acids than when they are fed concentrates (Jakobsen 1999). When lambs are fed with linseed, the amount of ω-3 fatty acids increased and similar findings with EPA and DHA have been reported in lambs fed a mixture of fish oil and marine algae (Elmore *et al.* 2005). Feeding with palm oil supplements enriches the meat lipids with saturated fatty acids, especially palmitic acid (Castro *et al.* 2005). However, the nutritional importance of increased α-linolenic acid concentration is not clear since α-linolenic acid is not as bioactive as longer chain omega-3 fatty acids such as EPA and DHA (Harris 2007) and since the total increase in omega-3 fatty acids in an 85 g portion of grass feed beef is generally less than 50 mg which is less than 10% of current recommendation of 500 mg omega-3 fatty acids per day (Harris 2007).

Conjugated linoleic acids (CLA) are the natural components of the foods of animal origin, also have been proved as beneficial. Numerous health benefits have been attributed to CLA in experimental animal models over the past two decades that include ameliorating carcinogens, atherosclerosis, onset of diabetes and obesity. CLA is also a potent regulator of body fat accumulation and retention. Enrichment of poultry meat with CLA may affect meat quality through increase in SFA in tissues. The increase in SFA resulted in higher penetration resistance values of breast meat. Although the increase in resistance was distinct, no negative effect on sensory attributes was observed, rather, there was a tendency toward improved sensory quality. Further, enrichment of chicken breast meat with CLA resulted in darker and less yellow colour. Obviously, the changes in the composition of fatty acids also altered color. For pig, feeding 1% CLA in oil decreased the proportion of unsaturated fatty acid significantly and increased saturated fatty acids in both belly fat and *Longissimus dorsi* muscle (Eggert *et al.* 2001). Similar effects of dietary CLA on the modification of fatty acid in pig tissues were also reported by others (Joo *et al.* 2002). Usually, greater concentration of CLA are present in ruminant meat than that from non-ruminants and it can be naturally synthesized in the rumen by bacteria *Butyrivibrio fibrisolvens* via the Δ-9-desaturase of trans 11 octadecanoic acid pathway (Pollard *et al.* 1980). It has been reported that the total CLA content in intramuscular fat from steers fed with pasture was greater than that fed with concentrates (Realini *et al.* 2004). However, many workers have reported the ill effects of dietary CLA on the sensory attributes of meat and meat products (Du and Ahn 2002; Du *et al.* 2003). Dietary addition of 5% CLA resulted in lower instrumental colour values viz., lightness and yellowness after 7 days of refrigerated storage (Joo *et al.* 2002).

Lowering cholesterol content: Dietary cholesterol is insignificantly correlated with the serum cholesterol levels. The consumers are scared of cholesterol rich foods like meat and prefer meat with high protein, low fat and low cholesterol. In general meat contains about 70 mg of cholesterol per 100 g of meat but leaner the meat lower the cholesterol in it. Some studies were conducted towards lowering carcass cholesterol content by dietary interventions using chromium, copper, nicotinic acid, statins, garlic, basil (tulasi), plant sterols, *n*-3 PUFA supplementation to chicken feed. Dehydrated alfa-alfa meal reduces cholesterol content and total lipids in chicken breast meat. Sunflower oil, soybean oil, canola oil, linseed oil reduces fat and cholesterol content in cockerel thigh and breast meat. Moreover, these substances are having synergistic effect in reducing the cholesterol levels. Hence, a combination of these supplements will be more beneficial, rather than a single substance. However, the cost of production of such lean meat will be higher due to lower body weight and poor feed efficiency. In a study it has been observed that chromium picolinate at 0.5 ppm had significantly lowered the carcass fat level. Neomycin sulphate at 5-10 ppm level also produced lean meat. Chromium enriched yeast at 1 g/kg diet improved the carcass quality. Organic chromium had increased the weight of pectoral muscles and the meat had less fat and cholesterol content. Increasing the lysine level in the pre-starter diets and methionine level in the finisher diets increased the lean breast meat yield in broilers.

Application of antioxidants: The antioxidants act through prevention of radical formation (e.g., superoxide dismutase, glutathione peroxidase), or prevention and restriction of chain formation and propagation (e.g., vitamins A, E, C, carotenoids), and excision and repair of damaged parts of molecules (e.g., lipases, peptidases, DNA repair enzymes) (Surai 2002). The most important natural antioxidant, α-tocopherol, is involved in the second level of defense, whereas, Se is involved in the first level (glutathione peroxidase). Both antioxidants reduce the risk of cancer and the incidence of cardiovascular diseases in humans.

Vitamin E (α-tocopherol acetate) is a naturally occurring antioxidant had been reported to be effective in improving meat color and lipid stability in pork, beef and lamb (Guidera 1997) through delaying oxidation. Vitamin E is possibly involved in fresh meat quality by regulating the conversion of muscle to meat by inhibiting protein oxidation. It has been reported that dietary vitamin E caused faster degradation of troponin-T at 2 days postmortem in beef steaks through decreasing the levels of protein oxidation. A lower shear force in beef steaks from *Longissimus dorsi* after 14 day of postmortem storage was reported by Carnagey *et al.* (2008) after feeding a diet supplemented with 1000 IU vitamin E for 104 days before slaughter. It has been reported that high level of vitamin E in poultry meat not only improve the oxidative stability but also prevent excessive drip loss, as it is believed that á-tocopherol maintain the integrity of cellular membranes, reduces leakage of sarcoplasmic components from muscle cells thereby reduces drip (Goni *et al.* 2007). It is also reported that under heat stress condition dietary vitamin E supplementation improved the immune response of broilers (Niu *et al.* 2009). Even supplementation of vitamin E decreased the production of fishy flavour because of fishmeal oil in diet and warmed over flavour in refrigerated cooked meat and raw frozen meat.

The effects of vitamin E in ducks are different. The effect of feeding of á-tocopheryle acetate at different levels to day old white Peking ducklings revealed significantly increased concentrations of vitamin E in breast, thigh, liver and heart tissues in dose dependant manner. Supplementation, though enhance oxidative stability but it was more effective for thigh muscle than breast.

Many plants, vegetables, herbs and their essential oils are good sources of natural antioxidants, such as phenolic compounds (eugenol, thymol, and carvacrol), flavonoids, cyaniding glycosides etc. It is considered that the antioxidant activity of these compounds is due to their high redox properties and chemical structure, which can be responsible for neutralizing free radicals, chelating transitional metals and quenching singlet and triplet oxygen by delocalization or decomposing peroxides.

Trace elements: Trace elements like cobalt, copper, iron, iodine, manganese, selenium, zinc are functional, structural, and regulatory components of numerous bio-molecules in the living organism. The intake of several essential trace elements is suboptimal in many countries around the world. Low- and middle-income countries are most affected, but the prevalence of iron and iodine deficiency, for example, is also high in high-income countries. Muscle is a good carrier of several essential trace elements, providing these elements mostly in an organic, well-absorbable form. Similarly to essential fatty acids, increasing or optimizing the content of essential trace elements in meat might positively contribute to human health.

The role of dietary selenium (Se) is in influencing the quality of poultry meat and other meat products. It has revealed that organic selenium supplementation in broiler showed a positive effect on weight gain, drip losses and FCR compared to controls. The researchers have also suggested that inclusion of selenium in broilers diet improve visual colour and oxidative rancidity (Tyagi *et al.* 2005). The supplementation of manganese (Mn) affected abnormal fat percentage, pH in breast muscle, MDA content, and manganese dependant super-oxide dismutase activities in thigh muscle, and lipoprotein lipase activities in abdominal fat. Cobalt is a particular trace element since it's only known function is as an essential component of vitamin B_{12}. Humans and monogastric animals including poultry do not require cobalt but they require vitamin B_{12}, whereas, the ruminant microflora can synthesize vitamin B_{12}, provided dietary cobalt is available in sufficient quantities. However, in muscle there was only a response in the case of deficiency. This means that the potential enrichment of animal foods above average current levels is negligible for most elements, taking into account the poor response in muscle for most elements. The greatest potential exists for iodine and for selenium in case an organic source is used.

Prebiotics and probiotics: Pre-biotics are non-digestible compounds present in feed ingredients. These are mainly oligosaccharides with 2-20 units of monosaccharide and are found in soybean and rapeseed meal. Legumes, cereals and yeast cell walls contain respectively galacto-oligosaccharides (GOS), fructo-oligosaccharides (FOS) and mannano-oligosaccharides (MOS). These compounds have been claimed as beneficial nutritional modifiers for most animals because of their ability to modify the gut microbial population by promoting the growth of beneficial flora in the intestines thereby providing a healthier intestinal environment.

Administration of *Bacillus subtilis* C–3102 to chickens reduced the number and incidence of *Salmonella* and *Campylobacter* in the intestinal tract of broilers. Carcass of broilers fed with probiotic had significantly lower *Salmonella*, *Campylobacter* and aerobic count than birds fed control diet (Frittis *et al.* 2000). The chicken carcasses fed diets with prebiotics had low Campylobacter and coliforms (Khaksefidi and Rahimi 2005). The prebiotics and probiotics in diet and fasting hour also influenced microbiological meat quality (Mandal *et al.* 2005). The antibacterial agent, lasalacid sodium salt (LS) added to the diet affected not only their growth performance but also their meat yield and stress response. Withdrawal of LS increased the plasma 2-thiobarbituric acid reactant value, an indicator of lipid peroxidation.

Manipulation of meat raw materials: It is possible to intervene at any stage in the process of transformation of muscle into meat and in the various different stages of raw material preparation to alter the meat composition and thereby achieve healthier products. The most immediate system consists of extensive trimming to remove external and internal fat from the carcass; further trimming is done on primal cuts and, where necessary, the defatting is completed on retail cuts. However, this is sometimes not feasible or desirable because of lower yields, costs and other considerations. Depending on the type of meat, raw materials and the required fat content, fairly complex physicochemical techniques have been applied, generally consisting of reducing the meat particle size before preparing (modifying the pH, ionic strength of the medium, etc.) and then proceeding to the actual extraction or separation processes based on cryoconcentration, centrifugation, decantation, etc.

Reformulation of meat products: The best way to alter the composition of foods is perhaps during one of the preparation stages. At this stage reformulation is used as far as possible to develop a range of derivatives with custom-designed composition and properties. For this, there are two possible types of complementary intervention. The first involves reducing some compounds normally present in these foods to appropriate amounts, for example, fat, SFAs, salt, nitrites and so on (Jimenez-Colmenero 2005; Biswas *et al.* 2011b; 2012a, b, c). The second is to incorporate ingredients that are potentially health-enhancing (functional), for example, fibre, certain types of vegetable protein, MUFAs and PUFAs, antioxidants (Bhosale *et al.* 2011a, b), etc. There are numerous aspects to be taken into account in the development of these kinds of products (Jimenez- Colmenero 2000). The new meat derivative must have the appropriate technological, sensory and nutritional properties, and be safe and convenient for consumption, etc. Ignoring such requirements, which are demanded by the reference products if they are to be improved, not only compromises the success of the derivatives concerned but also projects a bad image of these meat derivatives and creates a lack of confidence which is difficult to surmount. Some examples of meat product reformulation processes are reduction of fat content; modification of the fatty acid profile; reduction of cholesterol; reduction of calories; reduction of sodium content; reduction of nitrites and incorporation of functional ingredients.

Reduction of fat content and modification of fatty acid profile: Fatty acid composition of meat product can be modified by the formulation approach through the ingredients employed. The type of vegetable oil affects the fatty acid composition of a reformulated meat product. Vegetable oils are rich sources of MUFAs and PUFAs and are cholesterol-free. In order to improve their nutritional quality, various meat products have been made using oils from olive, high-oleic acid sunflower, linseed (flaxseed), soybean (Zhang and Zhou 2010), peanut, palm, etc. Besides providing a source of various health-promoting fatty acids, vegetable oils have been used because they contain a wide range of other bioactive compounds, some of them are antioxidant.

Olive oil is the most monounsaturated vegetable oil and has a high biological value, attributed to a high ratio of vitamin E to PUFA. It has a lower ratio of saturated to MUFA than any other vegetable oil and contains antioxidant substances in optimum concentrations (Bloukas *et al* 1997). Olive oil intake is associated with a lesser risk of heart disease, breast cancer, colon cancer, postprandial lipid metabolism and thrombosis and inhibits LDL oxidation (Luruena-Martinez *et al*. 2004). Partial substitution of pork back fat by olive oil has been tried in various cooked and cured meat products, adding between 1 and 10 g of olive oil per 100g of product. Olive oil increases MUFA in meat products without significantly altering the n-6/n-3 PUFA ratio (Ansorena and Astiasaran 2004).

Numerous plant materials have been used as ingredients in meat products. Walnuts have a high fat content (62-68%) and are rich in MUFAs (oleic acid, 18%) and PUFAs. Olmedilla-Alonso *et al*. (2006) reported health benefits of walnut consumption with respect to the risk of coronary heart disease. The FDA recently authorized a qualified health claim indicating that eating 42.5 g per day of walnuts, as part of a low saturated fat and low-cholesterol diet not resulting in increased caloric intake, may reduce the risk of CVD.

Marine oils have been used to supply substantial amounts of n-3 PUFAs in order to produce n-3 PUFA-enriched meat products. Fish oils containing approximately 22% EPA, 3% DPA and 22% DHA (Pelser *et al*. 2007) are one of the food sources of long chain n-3 PUFAs. The two main problems associated with them are susceptibility to lipid oxidation and a residual fishy aroma and taste. These problems can often be minimized by refining and deodorizing the oil, and by applying various antioxidant strategies (Garg *et al*. 2006). Fish oil has been used in various forms and levels to enrich different food products with long chain n-3 PUFAs. Some marine algae produce DHA-rich oil (40%). Algal oil has been used to produce meat products. Fatty acid profiles of meat products have been improved by direct addition of CLA to pork patties (Joo *et al* 2000) or beef patties (Chae *et al*. 2004) and by injection into beef strip loin (Baublits *et al*. 2007).

Reduction of cholesterol level in meat products: The content of cholesterol in meat and meat products is influenced by a variety of different factors, such as type of meat, the cut, and the preparation conditions. Despite these variations, the concentration of cholesterol generally varies between 75 - 95 mg per 100 g of meat with the notable exception of viscera such as kidney, heart, and liver that have significantly higher cholesterol contents at 300–375 mg per 100 g of meat (Chizzolini *et al*. 1998). Recommendations for daily allowances generally state that cholesterol intake should be limited to less than 300 mg per day (WHO 2003). A reduced fat content and its replacement with lean meat do not necessarily decrease the amount of cholesterol in meat products. To generate meat products that contain less cholesterol, fat and lean meat in raw material must be replaced by plant materials such as vegetable oils or proteins as they are intrinsically lower in cholesterol than animal tissue.

Sodium reduction in processed meat products: Sodium chloride in meat products is an essential ingredient providing simultaneously a number of different functionalities like reduce water activity, improve flavor, texture, gel forming ability etc. Salt is responsible to stabilize the interface of meat fats thereby forming a stable emulsion (Desmond 2007). Despite these key functionalities that are essential for the manufacturing of many meat products, there is increasing pressure from a large number of organizations to reduce both salt and sodium content in meat because a direct relationship between an excessive intake of sodium and an increased incidence of hypertension (McGregor 2007). The WHO recommends as little as 5 g of salt per day, which is equivalent to 2 g sodium per day. The consumption of meat and meat products contributes about 16– 25% to the total daily intake of sodium chloride.

The most commonly used method to date is replacement of NaCl by KCl. However, potassium chloride has a slightly bitter taste and to prevent the product from having unacceptable sensory properties, masking substances have to additionally be added to the products. The relatively new and not yet fully explored approach is to change the physical structure of sodium chloride. A change in particle size of undissolved salt crystals could lead to a more rapid dissolution behavior in the mouth thereby yielding a more pronounced salty taste of the product. However, to prevent excessive growth of salt crystals, this approach may need to be combined with an additional modification changing the physical state of salt from a crystal to a glass. The most common substances used in combination with sodium and potassium chloride are phosphates, salts of organic acids or carbohydrate such as trehalose or sucrose. Phosphates in addition to promoting saltiness simultaneously improve the water-binding capacity and cooking loss.

Nitrite reduction in meat products: Nitrite has many functions in meat products besides its main role in inhibition for the growth of *Clostridium botulinum*. Nitrite contributes to the development of cure colour and flavour; also inhibit rancidity and off-odours during storage. But in the recent years, the use of nitrites has become a key issue for the meat industry because of their relation in health related issues since under certain circumstances it reacts with amines to form nitrosamines which seem to be carcinogenic (Jakszyn and Gonzalez 2006). The nitrosamines formation in meat products can be reduced by avoiding direct addition of nitrite into meat, instead adding ingredients that have natural high nitrate content (Sebranek and Bacus 2007). Alternative to this, naturally occurring antimicrobials may be added into meat products. But problems with the natural antimicrobials is that it has very limited activity, so a replacement of nitrite by a single antimicrobial is difficult, and a combination of antimicrobials is required (Sofos 2008).

Ntzimani *et al.* (2010) added EDTA, lysozyme, rosemary and oregano oil to chicken meat stored in vacuum packages at 4°C. They showed that combinations were effective against the growth of Gram-positive bacteria Gram-negative bacteria and to a lesser degree yeasts. Combinations of nisin with oregano oil were tested in minced sheep meat during refrigerated storage (Govaris *et al.* 2010). In other products by the use of delivery systems for antimicrobials may be taken into account (Gaysinsky *et al.* 2008). These studies have demonstrated that problems of incompatibilities of antimicrobials with food matrix properties can be overcome by delivering naturally occurring antimicrobials in nano and microscalar carrier systems such as emulsion, liposomes, microemulsions, hydrogel particles and others.

Sanitation of meat surfaces prior to grinding or prior to the production of batters may improve the control of growth of food borne pathogens. Applications such as electrolyzed oxidizing water (Fabrizio and Cutter 2005), high pressure in combination with antimicrobials (Hugas *et al.* 2002), irradiation and light pulses (Aymerich *et al.* 2008), and surface sanitizers such as chlorine dioxide, cetylpyridinium chloride, and lactic acid (Jiminez-Villarreal *et al.* 2003) could extend shelf life of meat. Another surface treatment that is known to improve shelf life is the application of marinates (Björkroth 2005). They are often used in combination with modified atmosphere packaging. Combinations of these approaches may be able to reduce levels of microbes.

Reduction of calories: As per the dietary recommendations, both the total caloric content and the percentage of calories from fat will be the new criteria for evaluation of consumer-manipulated foods and that can be achieved by pre-blending of meat before finalizing the standard formulation. Calorie intake is most frequently limited by reducing the proportion of fat, where the content is more than twice that of proteins or carbohydrates, but the role of fat replacement should not be ignored. Simple fat reduction helps limit the calorie intake from meat products, but in many cases this may not be sufficient to meet WHOs dietary recommendations. So, it is only possible to reduce the intake of fat from lipids to 30%, either by drastically reducing fat content to around 2%, or by diluting it with fat replacements or substitutes that improve the protein/fat/carbohydrate balance.

Incorporation of functional ingredients: The health benefits of certain substances in food have been recognized for some time now. However, only recently their role in the treatment and prevention of various diseases, or their long-term impact on ageing processes has been established. A wide range of ingredients have been identified as having potentially beneficial effects for human health like dietary fibre, oligosaccharides, sugars/alcohols, amino acids, peptides and proteins (Xiong *et al.* 2008), glucosides, alcohols, isoprenes and vitamins, choline (McCann *et al.* 2005), lactic acid bacteria, minerals, unsaturated fatty acids, antioxidants etc. Many of these ingredients have been or are currently being studied, and the results obtained are very different. The use of one or more of these ingredients in meat products has opened up an enormous range of possibilities.

Some examples of functional ingredients in meat derivatives are dietary fibres from oat, sugar beet, soy, apple, pea, etc., have been included in the formulation of several meat products (Cofrades *et al.* 2000; Biswas *et al.* 2014). Inulin, a polymer of fructose with health enhancing properties extracted from chicory (Pszczola 1998), is being used in products like sausages or cooked ham. Protein derivatives of vegetable origin have been used in meat products for technological purposes to reduce formulation costs and they have been used for their nutritional value. Soy and sunflower proteins, wheat and maize derivatives, and flours from cottonseed and oats, some of which contain health-enhancing substances, have all been used as fat replacers (Keeton 1994). Sunflower protein is rich in L-arginine, which combined with a low L-lysine/L-arginine ratio, is extremely useful in the prevention of hypercholesterolaemia and platelet aggregation. Some microorganisms occurring in fermentative processes are also under use to ensure microbial activity. This activity helps digestion by reducing the absorption of fat and cholesterol and promoting the assimilation of nutrients.

Table 1: Some natural antioxidants incorporated to make healthier meat products

Source	Part	Meat product	Active component	Added level
		Plant Sources		
Aloe vera	Crude gel	Enrobed goat meat bites	Aloin, aloe-emodin, barbloin, emodin, anthraquinone glycosides	3%
Apple peel	Methanol extract	Enrobed goat meat bites	Flavonols, flavones, anthocyanins	3%
Bamboo	Leaves	Fried chicken wings	Flavones, lactones, phenolic acids	0.5%
Beetroot	Ethanol Extract	Chicken meat balls	-	0.5 ml/kg
Canola	Seed extract	Chicken meat	-	500 and 1000 ppm
Cinnamon	Cinnamon powder	Minced chicken meat	Cinnamldehyde, Eugenol, cinnamicaldehyde	2%
Dry Honey		Turkey slices		15%
Garlic	Fresh garlic	Chicken sausages	Allicin, diallyl sulfide and diallyl trisulfide	50 g/kg
	Garlic powder	Chicken sausages	-	9 g/kg
	Garlic oil	Chicken sausages	-	0.06 g/kg
Grapes	Peed extract (GSE)	Turkey meat	Proanthocyaninidins	0.1 %
	GADF	Chicken hamburger	Flavonoids	2 %
	Pomace (dietary)	Chicken patties	-	60 parts GPC
Green tea	Leaves/extract	Raw poultry meat	Catechins- epicatechins,-epigallocatechin, epigallocatechin gallate, Epicatechin gallate	200-400 mg/kg
	(Dietary)	Poultry feed	-	300 mg/kg
Honey	-	Turkey slices	-	15%
Onion	Freeze-dried onion powder	Cooked chicken meat	Quercetin	1.6 %
	Juices	Turkey breast rolls	Quercetin	50 % strength onion juice brine
Oregano	Oil and extracts	Turkey meat	Rosmarinic acid	200 mg/kg
Plums	Plum extract	Turkey breast rolls	Chlorogenic acid neoclorogenic acid, cryptochlorogenic acid	>2 %
Potato	Peel Extract	Irradiated meat	Catechin, chlorogenic acid	0.04 %
Pomegranate	Juice rind powder	Chicken patties	Tannins, anthocyanins and flavonoids	10 m.equ/100 g
Red guava	Pomace ethanolic extract		Chicken meat rolls ß-carotene phenolic compounds of meat	Lycopene and 60 mg GAE/kg
Rice	Hull Extract	Turkey breast	Phenolic compounds	0.1%, w/w
Rosemary	Extract	Cooked turkey products	Phenolic diterpenes, phenolic acids	500ppm
Sage	Oil	Chicken meat	Carnosol, rosmanol, rosemadiol, carnosic acid	3 %
Sesame Oil	Sesamol	Chicken patties	Phenolic compounds	500– 2000 μg/ml
	Dry soya sprouts	Chicken patties		30 g/ kg
Tea catechins		Cooked chicken duck and ostrich patties	Catechins	300mg/kg minced muscle
		Animal Sources		
Milk proteins	Casein phosphopeptides	Muscle foods	-	2 %

- Data not recorded.

Lipid component in food for health has prompted the emergence of various procedures to alter their presence both quantitatively and qualitatively. It has been reported that CLA which is found in heat-treated meat products has some anti-mutagenic and anti-carcinogenic properties (Hasler 1998). A number of strategies are being used to enhance antioxidant activity in meat systems **(Table 1**) and to reduce the formation of oxidation products with their subsequent impact on ageing, cancer and cardiovascular disease (Ahmad *et al.* 2015; Brewer 2011). Fasseas *et al.* (2008) reported that bovine and porcine ground meat incorporated with oregano and sage essential oils @ 3% w/v exhibited reduced oxidation of raw and cooked meat during stored at 4 °C. More recently, Biswas *et al.* (2015) studied antioxidant activity of apple peel paste (APP), banana peel paste (BPP), aloe vera gel (AVG) and drumstick leaf powder (DLP) and these compounds were added at 2.0, 2.5, 2.0 and 0.5 g/100 g, respectively in poultry meat wafer formulation. While evaluating AOA of marjoram, Muchuweti *et al.* (2007) reported that it contained the highest proportion of simple phenolic compounds (95.57%) which exhibited highest radical scavenging activity of 91.3%. Various plant obtained ingredients rich in vitamin E have been added to the meat products during processing, including walnut in restructured steak (Serrano *et al.* 2005), rice bran oil in roast beef (Kim *et al.* 2000) and wheat germ in frankfurters (Gnanasambandam and Zayaz 1992).

Ascorbic acid has been used in several meat products either in isolated form or in the form of some incorporated ingredients like in beef patties (Sanchez-Escalante *et al.* 2003), dry cured sausages (Fernandez Lopez *et al.* 2004) and cooked pork. Some of the carotenoid rich vegetables are used as ingredients in some processed meat products as non-meat ingredients. Several carotenoids have been used as exogenous added antioxidants in meat products.

Lycopene has been added in beef patties (Desmond and Troy 2004), restructured beef steak, frankfurters, and liver or meat loaves have been prepared with plant derived ingredients such as tomato pulp/juice that is lycopene rich (Yilmaz *et al.* 2002), carrot and sweet potato rich in provitamin A (Devatkal *et al.* 2004) or spinach rich in lutein and zeaxanthin (Pizzocaro *et al.* 1998). Phytates have been incorporated in meat products in the form of sodium phytate (commercial preparation) in restructured beef (Lee *et al.* 1998) or as components of any of a number of phytate rich plants added to different meat products, such as rice fiber in beef roast (Kim *et al.* 2000). Since a voluminous work has been conducted to evaluate AOA of plants, herbs, spices, vegetables, animal derived peptides etc.

Probiotic meat products: In recent years, the possibility of development of probiotic meat products has been discussed in the field of meat science and industry (Arihara 2004). By using probiotic bacteria like *Lactobacillus acidophilus*, *Lactobacillus casei*, *Bifidobacterium* spp., etc, potential health benefits can be introduced to meat products (Sameshima *et al.* 1998). Target products with probiotic bacteria are mainly dry sausages, which are processed by fermentation without heat treatment. Jahreis *et al.* (2002) have studied the utilization of probiotic lactic acid bacteria (*Lactobacillus paracasei*) as a starter culture for a moist type of fermented sausage. The effect of probiotic bacteria on the formation of CLA in media and fermented milk products has been demonstrated (Xu *et al*. 2005), such effect would be also expected in fermented meat products. As described above, CLA is an attractive bioactive compound for designing functional products. Such novel functional fermented meat products with probiotics and CLA would have a market.

Prebiotics and synbiotics: In the food industry, much interest has also been shown in the utilization of prebiotics. Several prebiotic substances are known to enhance the activity of probiotic bacteria (Playne *et al*. 2003). Oligosaccharides and dietary fibers are representative prebiotic substances used for processed meat. Some desirable attributes in functionally enhanced prebiotics listed by Rastall (2000). In another aspect, a mixture of probiotics and prebiotics, also known as synbiotics which are proposed by Gibson and Roberfroid (1995), is utilized for many foods, such as fermented meat products. Since meat products with probiotics, prebiotics and synbiotics have a great future potential, it is expected that increasing interest will be shown in basic research and potential applications for designing new meat products.

CONCLUSION

Healthier meat production through dietary approaches provides better option for consumers who want those products with different nutritional health benefits than conventional ones. However, major changes that can also be brought in meat and meat products are through manipulation of meat raw materials, alteration of meat products formulations and process modification for increase of protein with concomitant decrease in fat, enrichment of meat with fatty acids, fat-soluble vitamins and probably certain minerals. Numerous nutritional and non-nutritional factors have been demonstrated to alter fat deposition and cholesterol contents in meat. However, healthier meat and poultry products should be produced economically, salable profitably, and safe for human consumption. Designing must take into consideration the particular production facilities, available materials, know-how, and economic resources of the producers. Moreover, the welfare aspects and production potentiality of animals and birds, and also environmental issues must be taken care of in the process of healthier meat and meat products.

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