J Food Sci Technol (November–December 2012) 49(6):653–664
DOI 10.1007/s13197-011-0476-z

REVIEW

Characteristics and consumer acceptance of healthier meat and meat product formulations—a review

Swapna C. Hathwar · Amit Kumar Rai · Vinod Kumar Modi · Bhaskar Narayan

Revised: 14 July 2011 / Accepted: 26 July 2011 / Published online: 2 August 2011
© Association of Food Scientists & Technologists (India) 2011

Abstract Awareness of health and nutrition has led to the development of "*functional foods*" which is a new approach to achieve healthier status thus reducing the risk of diseases. Meat has been highly exploited as a functional ingredient/food in recent years wherein meat has either been modified or incorporated into non meat products. Changing consumer demand has influenced the market for all types of meat. The development and marketing the functional foods can be, however, very challenging compared to the foods that conventionally have a high health image. This review gives the overall perception about importance of using meat/meat products as a functional food.

Keywords Functional food · Healthier meat based products · n3 enriched egg · Carotenoid

Meat is a good source of dietary proteins in many countries and provides high biological value. Apart from being important sources of proteins, vitamins and minerals, it also provide fat including saturated fatty acids (SFA), unsaturated fatty acids (USFA), cholesterol, triacylglycerol and phospholipids. Thus, consumers often associate meat with a negative image as a high fat and cancer-promoting food (Valsta et al. 2005). Some of these negative nutrients can be minimized by selection of lean meat cuts, removal of adipose fat, dietary manipulation to alter fatty acid composition and proper portion control to decrease fat consumption and caloric intake. As meat is by itself rich in nutrients such as fatty acids, minerals, dietary fiber, antioxidants and bioactive peptides, their incorporation into other products would alter the nutritional and biofunctional value of the product positively. Recently researchers also have revealed the possibility of developing meat products with potential health benefits by increasing or introducing bioactive properties (Arihara et al. 2004).

S. C. Hathwar · A. K. Rai · V. K. Modi · B. Narayan (✉)
Department of Meat, Fish & Poultry Technology,
Central Food Technological Research Institute (CFTRI),
Council of Scientific & Industrial Research (CSIR),
Mysore 570 020, India
e-mail: bhaskar@cftri.res.in

B. Narayan
e-mail: bhasg3@yahoo.co.in

Nutraceutical or functional food?

The words *nutraceutical* and *functional food* are wrongly interpreted to be one and the same though there is a difference between the two. A functional food is one which is *similar in appearance to a conventional food, consumed as part of the usual diet, with demonstrated physiological benefits, and/or to reduce the risk of chronic disease beyond basic nutritional functions* and a nutraceutical is *a product isolated or purified from foods that is generally sold in medicinal forms not usually associated with foods* (Health Canada 1998). A nutraceutical can be a part of functional foods while the latter has to provide essential nutrients often beyond qualities necessary for normal maintenance, growth, development and other biologically active compounds that impart health benefits or desirable physiological effects. The definitions and regulations regarding functional foods/ingredients vary from country to country.

Functional foods stand for a category of remarkably promising foods bearing beneficial characteristics like cholesterol lowering-, antioxidant-, and anticancer properties that have looked upon to be quite appealing by the consumers. It is mainly endorsed in developed countries, due to the increased life expectancy, high health care costs, advances in food and ingredients technology, the need for publicly funded research institutions to publicize their findings and the greater media coverage given to health issues (Ioannis and Maria 2005). The demand from consumers for healthful food has initiated a surge of research and product development in the food industry. In order to adapt to these consumer drivers, the food industry is reformulating food products to enhance the physiological functionality of inherent nutrients or by adding bioactives with largely clinically proven physiological function (Day et al. 2009). The functionality of functional foods derived from bioactive ingredients (Ferrari 2004) depends on several technological factors like fermentation, daily dosage, targeted compound, stability, food matrix formulation, viability, encapsulation, drying/heating technology and aseptic packaging.

Methods of enrichment of functional ingredients

There are two major routes for effective administration of functional materials *viz.*, direct and indirect administration.

Direct administration The functional materials can be directly incorporated into the daily diet of consumers. As this type of administration involves several regulatory clearances—in terms of proven clinical data, bioavailability of the product, clearances from the food regulatory authorities and acceptance by the consumer in tune with the ethnic considerations—direct administration of functional ingredients is more stringent and reasonably difficult act to follow. A schematic representation of the possible ways to enhance the functionality of meat/meat products is shown in Fig. 1.

Indirect administration This method aims to deliver through livestock/cultured animals consumed regularly by the consumer. This is more affordable in terms of delivery as well as clearance from food standards. However, the efficacy of uptake by the cultured animal needs to be proven before any claim to the beneficial effect is made. The utility value and final application of functional materials or ingredients depend on four major factors—availability, sustainability, marketability and acceptance (Nimish et al. 2011).

Meat incorporated food

Although reports available on biological activity of phytochemicals from vegetables are abundant (Ferrari 2004), there have been very few reports on physiological functions of meat or meat ingredients (Arihara 2006; Blandino et al. 2003). The incorporation of meat/fish into other products would positively influence the nutritional and biofunctional value of the product. Meat can be incorporated into various food products either directly (as fermented or hydrolysed meat) or as protein hydrolysates obtained through fermentation by lactic acid bacteria (LAB) or enzymatic treatments.

Direct incorporation of meat or meat hydrolysates Cereal grains are considered to be one of the most important sources of dietary proteins, carbohydrates, vitamins, minerals and fiber all over the world. However, the nutritional quality of cereals and the sensorial properties of their products are inferior due to the lower protein content, deficiency of certain essential amino acids, low starch availability, presence of determined antinutrients and coarse nature of the grains (Blandino et al. 2003). Incorporation of meat could be a simple way of improving their nutritional value and biofunctionality. Meats from natural sources like chicken or fish can be readily incorporated into wheat or rice based products and such incorporation would result in balancing the amino acid and fatty acid composition

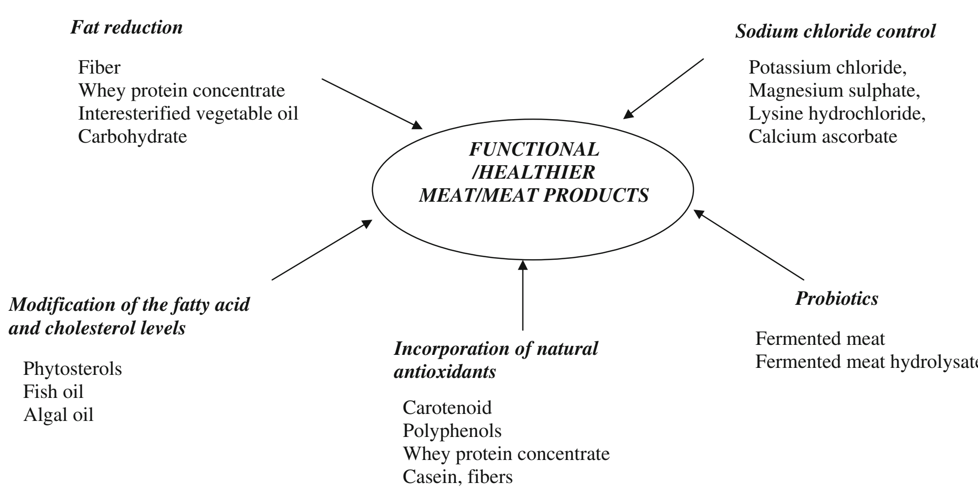

Fig. 1 Possible ways of modifying nutritional and functional characteristics of meat and meat products

(Prabhashankar et al. 2009), as reported recently. Regular rabbit meat consumption could provide consumers with bioactive compounds because rabbit diet manipulation is very effective in increasing levels of PUFA, CLA, EPA, HA, vitamin E, selenium etc. (Zotte 2002; Zotte and Szendro 2011) and the lowering the n-6/n-3 ratio that plays a key role in controlling CVD and other chronic diseases (Zotte and Szendro 2011). Compared to meats of other animal species, rabbit meat has lower cholesterol contents and high levels of protein with essential amino acids, especially in the *L. dorsi* muscle, which also has a high digestibility value (Zotte et al. 2006).

Dietary proteins are a well known source of biologically active peptides. These peptides are inactive within the sequence of parent protein and can be released during gastrointestinal digestion or food processing. Once bioactive peptides are liberated, they may act as regulatory compounds with hormone-like activity. Pure protein hydrolysates have been shown to have valuable dietetic properties and high nutritional value (Korhonen et al. 1998). They also possess possible bioactivities extending beyond their property as nutritional sources of amino acids alone like antioxidative, antihypertensive, immunomodulatory, antimicrobial, antithrombic and hypocholesterolemic properties (Arihara 2006).

Meat Protein Hydrolysates (MPH) can be obtained by addition of proteases on a commercial scale in order to incorporate it into products. During hydrolysis using proteases, fat and other unwanted materials can be removed by separation. The MPH possess functional protein-binding properties of the original material which can be used in improving processed meats. It can either be injected into meat cuts or used in emulsified products. Its dried form can be used in various food products such as meat, condiments, flavourings, sauces and soups, as it is known to improve taste, water retention and is easily digestible (Neklyudov et al. 2000), as well as significantly lower the production costs for the final meat product. The product would have several benefits like improved slicing and tenderness, improved production economy, flavour, firmness and protein distribution (Arihara 2006; Jimenez-Colmenero et al. 2001).

MPH also find application in nutritional management of individuals who cannot digest whole protein. The most prevalent application of protein hydrolysate has been for feeding infants with food hypersensitivity (Nimish et al. 2011). The antioxidative properties exhibited by meat/fish protein hydrolysates are mainly due to the several endogenous antioxidants present in skeletal muscle (Table 1). Fish protein hydrolysate is known not only to elevate plasma bile acids, reduce visceral adipose tissue mass in rats (Liaset et al. 2009) but also reported to truncate the increased intestinal permeability in humans (Marchbank et al. 2008). It is also reportedly known to reduce the symptoms of occasional diarrhoea and constipation, and alleviated bloating (Englender 2000). It may have benefit for the protection and stimulation of repair distal to the stomach. (Marchbank et al. 2009; Fitzgerald et al. 2005). These fish proteins when supplemented to flours could contribute significantly to the protein intake of population of developing country. These bioactive peptides may act as potential physiological modulators of metabolism during the intestinal digestion of the diet.

Generation of bioactive peptides in fermented meat products is another possible direction for introducing physiological functions. Bioactive peptides would be generated in fermented meat products since meat proteins

Table 1 Meat based bioactive compounds and their biofunctionalities

Meat based bioactive substances	Functionality	Reference
Carnitine	Putative ergogenic agents, long chain fatty acid carrier across the mitochondrial membrane and in ketone body formation, hypocholesterolemic and immunomodulatory effect.	1, 2
Carnosine	Decreased brain lipid peroxidation, periophtalmic lesions, increased reactivity of a senescence accelerated mice line, buffering capacity and antioxidative effect.	3, 4
Coenzyme Q10	Improves mitochondrial respiration and enhances post-ischemic myocardial contractile function and decreases myocardial damage, Antioxidative and cardiovascular effects	2, 5
α-lipoic acid	Decreased heart mitochondrial DNA oxidation, antioxidative effect.	2, 6
Choline	Putative ergogenic agents, reduces urinary carnitine excretion, methyl group metabolism and lipid transport	2
Taurine	Stimulates bile acid synthesis, hypolipedemic effect, hypocholesterolemic effect, cardiovascular effects	2, 6
Conjugated linoleic acid	Anticarcinogenic compound (colorectal cancer), antioxidative and immunomodulative properties; antiobesity, antidiabetic and modulation of bone metabolism	1
Anserine	Buffering capacity and antioxidant activity	4
Glutathione	Increase in absorption of heme iron	7

1 – Arihara 2006; 2 – Prates and Mateus 2002; 3 - Gallant et al. 2000; 4 - Zhou and Decker 1999; 5 – Rosenfeldt et al. 2002; 6 – Suh et al. 2001; 7- Miguel et al. 1984

are hydrolyzed by microbial proteases during fermentation. Developing functional fermented meat products could be an alternative process in the meat industry (Arihara. 2006) as it is known to destroy undesirable components producing a safer product (Blandino et al. 2003) also improving shelf life, texture, taste and aroma of the product. The presence of aromas make fermented meat based products more appetizing. Fermentation may also result in the synthesis of certain amino acids and improve the availability of B group vitamins**.** But, at the same time, certain cultures present in meat seem to pose safety issues. For instance,- *S aureus* has been responsible for food poisoning (Lucke 1998; Sameshima et al. 1998). In order to address these safety issues, the use of starter cultures mainly LAB as *functional starter cultures* has been suggested (De Vuyst 2000; Leroy and De Vuyst 2003, 2004). The preservative role of lactic fermentation technology and antibiosis mediated by LAB has been well documented. The main antimicrobial effect responsible for safety is reported to be the rate of acidification of the raw meat (Lucke 2000). Thus, the antimicrobial activity displayed by LAB strains due to acidification as well as bacteriocin production may be used to combat microbial contamination and also prove to be a better alternative for preservation instead of chemical food additives. (Lucke 2000; Holzapfel et al. 1995) Functional starter cultures not only contribute to microbial safety but also offer one or more organoleptic, technological, nutritional, or health advantages. Thus, the use of functional starter cultures especially LAB with an industrially or nutritionally important functionality has being highly explored.

Fermented sausages are a common fermented product in meat industry. These sausages help digestion by reducing absorption of fat and cholesterol and promoting assimilation of nutrients. Kefir is another fermented meat product obtained using *L kefir, L kefiranofacies, L brevis*. *L alimentarius*, *Carnobacterium piscicola* are used for fermented fish products (Leroy and De Vuyst 2004). The starter culture can be decisive for the sensory properties of the final product, since the ability of microorganisms to degrade amino acids to aroma compounds is highly strain dependent (Berdague et al. 1993). Relatively less attention has been focused on the consumption of fermented products and cancer risk, although an inverse relationship has been observed in some studies (Mital and Garg 1995). This may be due to the fact that lactic acid cultures can decrease the activity of faecal enzymes like β-glucuronidase, azoreductase, nitroreductase that are thought to play a role in the development of colon cancer (Prates and Mateus 2002). Fermented meat is also known to possess various other biofunctionalities such as alleviating symptoms of aging, fatigue, autism, allergies, and osteoporosis, antimicrobial, anticancerous, antiobesity, and antidiabetic effects, increasing availability of B group vitamins, and synthesis of amino acids (Cencic and Chingwaru 2010).

Marine oil (seaweed, fish)*,* rich in highly unsaturated fatty acids are responsible for many beneficial effects like hypocholesterolemic, anticarcinogenicity, antimutagenicity, antioxidative and antiaging activity, rheumatoid arthritis, and inflammatory bowel diseases (Kim and Mendis 2006; Terasaki et al. 2009). They can as well be incorporated into a variety of products (Table 2) as well as infant formula to improve the functionality of infant food (Nimish et al. 2011).

Chitosan, a fiber of animal origin is known to possess numerous technological and physiological properties useful in foods (Shahidi et al. 1999). Chitosan can be used as a functional ingredient as it acts as a gelling agent, emulsifier and food preservative (Borderıas et al. 2005). Its ability to absorb fat creates a new potential for use as an anti-cholesterol agent (Bokura and Kobayashi 2003). Incorporation of chitosan into foods like biscuits (Maezaki et al. 1993), meat products (Jo et al. 2001; Lin and Chao 2001), fish muscle (Benjakul et al. 2003; Kamil et al. 2002) and derivative products such as fish patties and sausages (Lopez-Caballero et al. 2005a, b) have been reported.

Table 2 Direct method of enrichment of food with functional ingredients

Ingredient	Product	Functionality	Reference
Meat hydrolysate	Meat, condiments, sauces, soups	Improved digestibility, taste, water retention.	1, 2
Fermented meat	Sausage, Kefir	improves shelf life, texture, taste and aroma, nutritive value	3
ω-3 rich oil	Bread, cereal products, spread, milk, mayonnaise and salad dressing, crackers, bars	firmness or softness of the fat, color, stability	4, 5
Carotenoid	Pasta, soups	food colouring agents	6, 7,8
Dietary fiber	Meat, meatballs, biscuits	water binding, gelling, chelating property, food preservative	9, 10, 11

1- Nimish et al. 2011; 2 - Neklyudov et al. 2000; 3 - Berdague et al. 1993; 4 – Garg et al. 2006; 5 – Bhaskar et al. 2008; 6 - Prabhashankar et al. 2009; 7 - NIIR Board 2004; 8 - Anon 2000; 9 – Borderıas et al. 2005; 10 – Alonso et al. 2006; 11 - Yilmaz 2004

Meat based food products

Meat and meat products are important sources of proteins, vitamins and minerals, but they also contain saturated fatty acids, cholesterol, and salt. In order to develop healthier meat products, an understanding of their positive and negative effects on health is needed. Therefore a product can be designed by improving or by modifying meat or meat products which will have the characteristics that suit customer's needs.

Meat product with improved lipid profile Lipid is one of the bioactive components that has received most attention, particularly with respect to the development of healthier meat products. Meat lipids contain less than 50% SFA and up to 70% USFA [monounsaturated fatty acid (MUFA) and polyunsaturated fatty acids (PUFA)] (Jimenez-Colmenero et al. 2001). Fatty acid composition has a considerable effect on the health since each fatty acid affects the circulation lipids differently (Jimenez-Colmenero et al. 2001; Bhaskar et al. 2006). The functionality of MUFA and PUFA in the diet reduces the level of plasma low density lipoproteins-cholesterol. Although it is frequently asserted that less fat in the diet is better, qualitative aspects of fat need to be taken into account, including the fact that some fatty acids are essential in our diet. For example—a high n-6/n-3 PUFA ratio was a greatest risk factor for arteriosclerosis and ischaemic heart disease but not hypercholesterolaemia. Also, variations in fatty acid composition have an important effect on firmness or softness of the fat in meat. Hur et al. (2004) reported substituted conjugated linoleic acid (CLA) sources for fat improved the color stability possibly by inhibition of lipid oxidation and oxymyoglobin oxidation. Vegetable/fish oils are rich sources of MUFAs and PUFAs and are cholesterol-free. Thus, in order to improve the nutritional quality and functionality, various meat products have been made using oils from olive, high-oleic acid sunflower, linseed (flaxseed), soybean, peanut, palm, fish etc. (Colmenero 2007; Kolanowski and Laufenberg 2006). Algal oil has also been used in meat products (Lee et al. 2006).

Fish oils have been considered as important sources of omega-3 fatty acids with varied functionalities. Functional food containing omega-3 lipids is one of the fastest growing food product categories. Regular consumption of long chain omega-3 PUFAs confers a number of health benefits as mentioned earlier. Levels of dietary fish oil significantly influence the n-3 fatty acid and cholesterol content of meat lipids (Jeun et al. 2002). Thus, meat products can be enriched with the various sources of omega-3 PUFA to elevate long chain omega-3 PUFA in the average diet. The off-flavours developed in omega-3 PUFA enriched food creates stability problem especially with regard to odor and taste to most food products (Colmenero 2007) and it is highly susceptible towards oxidation. The human sensory apparatus has a low threshold for volatile off-flavours resulting from oxidation of omega-3 PUFA (Jacobsen et al. 2008). To avoid the stability problem, fish oil could be added only to short shelf-life food products or it can be converted to powder by microencapsulation, a technique that changes the form of fish oil from liquid to powder and may stabilize the omega-3 PUFA. Such microencapsulated fish oil can be used for production of enriched bread and infant formula.

Phytosterols from plant sources (eg- sitosterol and campesterol) are known to have several bioactive qualities with possible implications for human health (Normen et al. 2002). They can be blood cholesterol lowering agents as they lower total and LDL blood cholesterol by preventing cholesterol absorption from the intestine. They are also believed to protect against certain types of cancer such as colon, breast and prostate (Awad and Fink 2000; Peter 2009). The enrichment of foods such as margarines with phytosterols is one of the recent developments in functional foods to enhance the cholesterol lowering ability of traditional food products (Taşan et al. 2006). Thus, incorporation of these phytosterols into the meat product would enhance the biofunctionality of the meat product (Jose et al. 2011).

Low fat meat product (addition of fiber, reduction of cholesterol and calories) Dietary fibers can be an effective tool for improving functional properties as mentioned earlier. There is an increased demand for foods with more fiber and less fat as they are very effective in prevention of fat absorption by the product, particularly fatty acids and cholesterol (Borderıas et al. 2005), that could be useful in reducing obesity. They are also known to possess chelating property to some minerals such as copper (Borderıas et al. 2005). Various types of fiber have been studied alone or combined with other ingredients for formulations of reduced fat meat products, largely ground and restructured products (Desmond et al. 1998; Mansour and Khalil 1999). Nuts are rich sources of dietary fiber. Alonso et al. (2006) demonstrated an inverse association between nut consumption and the risk of cardiovascular diseases (CHD) in various studies. Thus, incorporating nuts as a source of dietary fiber into meat/meat products would yield a low fat meat product also improving its functionality such as cholesterol lowering properties (Halsted 2003; Sadler 2004). Rye bran, which was reported to inhibit breast and colon tumor growth in animal models, to lower glucose response in diabetics, and to lower the risk of death from coronary heart disease. Rye bran was used as a fat substitute in the production of meatballs (Yilmaz 2004). The total trans fatty acid content was lower and the ratio of total unsaturated fatty acids to total saturated fatty acids was higher in the meatballs with added rye bran. There are reports (Modi et al. 2009; Prasad et al. 2011) on the use of carrageenan, oat and casein in meat products as fat replacers. Apart from reducing fat content, fibers also have numerous other health benefits like maintaining bowel integrity, antioxidative, antiobesity, hypocholesterolemic, antidiabetic, anticancerous, cardiovascular disease etc. (Borderıas et al. 2005).

Although low fat meat products are preferred as they are perceived to be healthier, they may have decreased meat quality attributes, especially juiciness and flavor, due to lower intramuscular fat content (Chizzolini et al. 1999). Thus, the partial replacement of meat fats with various non-meat fats (of plant and marine origin) into meat products is another option. Interesterified vegetable oils can also be used a fat replacer modifying without any detrimental changes in sensory characteristics (Colmenero 2007).

Also various other non-fat containing products have been used as fat replacers. Whey protein concentrate (WPC) (Naga et al. 2009), long chain oligosaccharide (inulin) products (Crittenden and Playne 1996) and some of the chemically modified starches (Tharanthan 2005) have been reported in many studies to be useful in fat replacement.

Sodium control Role of sodium in the development of hypertension in sodium-sensitive individuals is also a matter of concern as meat products usually tend to have high salt content on processing (Ruusunen and Puolanne 2005). A large percentage of population possesses a hereditary predisposition to arterial hypertension, the incidence of which is largely affected by high sodium intake (Jimenez-Colmenero et al. 2001). Potassium chloride is probably the most common salt substitute used in low- or reduced salt/sodium foods. (Hur et al. 2004; Ruusunen and Puolanne 2005). But this is known to impart bitterness and loss of saltiness. Partial replacement of sodium chloride (NaCl) by calcium ascorbate (Gimeno et al. 2001) seems to be a viable way of decreasing sodium in dry-fermented sausages. It would imply enrichment in ascorbate and calcium with advantages from the nutritional point of view. According to Ruusunen et al. (2005), the use of mineral salt mixtures is a good way to reduce the sodium content in meat products. The same perceived saltiness can be achieved with salt mixtures at lower sodium content. Some of these mixtures have been commercialised such as Pansalt —® a patented salt replacer where almost half of the sodium is removed and replaced with potassium chloride, magnesium sulphate and the essential amino acid l-lysine hydrochloride. According to the manufacturer, the patented usage of the amino acid enhances the saltiness of the salt replacer and masks the taste of potassium and magnesium, while increasing the excretion of sodium from the human body (Desmond 2006). Other commercially available mixtures of NaCl and potassium chloride include Lo® salt, Saxa So-low salt and Morton Lite Salt® amongst others. Studies by Morton salt found that ham, bacon and turkey ham products manufactured with Morton Lite Salt® with a 60:40 mixture of NaCl:KCl had similar flavour scores to the control salt products (Ruusunen and Puolanne 2005; Desmond 2006). Further studies have found that the Lite Salt® maintained protein hydration in meat products (Morton 1994).

Incorporation of natural antioxidants Dietary antioxidants have been suggested to be beneficial to immune function, heart disease and cancer (Fernandez et al. 2005). Vegetable products such as carotenoids (Chew et al. 1999), flavonoids and a range of other potentially beneficial phytochemicals are good sources of dietary antioxidants. Consumer concerns over safety and toxicity of synthetic antioxidants pressed the food industry to find natural sources (Coronado et al. 2002). These natural antioxidants can be incorporated into meat products to increase its functionality. WPC (Djordjevic et al. 2004; Ulu 2004), casein (Bzducha and Wolosiak 2006) and some fibers such as beetroot and cellulose (Bobek et al. 2000) are known to possess relatively better antioxidant capacity. Lipid oxidation which is a limiting factor for the storage stability and sensorily acceptability of meat products can be prevented by using these natural antioxidants (Garg et al. 2006).

Carotenoids from marine source especially shellfishes, are highly antioxidative making them a good candidate as functional food ingredients. Astaxanthin is known for its anti-ageing properties and canthaxanthin is reported to be effective in treatments for Alzheimer's and Parkinson's disease, high cholesterol, strokes and cancer (Guerin et al. 2003). Further more, beneficial effects of carotenoids and their metabolites on obesity, kidney and liver function, diabetes, and asthma have also been continuously reported based on *in-vivo* models. Seaweeds also are rich sources of carotenoid and have various applications in food industry as they have the potential as natural antioxidants such as carotenoid and polyphenols (Bhaskar et al. 2008). β-carotene is the predominant carotenoid in meat and meat products (Mortensen and Skibsted 2000) which ranges from 5–900 μg/100gm of different meat (Williams 2007). It functions as a dietary lipid-soluble antioxidant, with an important role in controlling oxidatively induced diseases such as cancer and atherosclerosis (Decker et al. 2000).

Non-meat products of animal origin

n-3 enriched egg Egg has been used as a food by human beings since antiquity. There is no other food of animal origin that is eaten by so many people worldwide. The nutritive quality of an egg enhances the value of any food it is incorporated into containing balanced amino acid composition and high proportion of n-6 PUFA as well but at the same time is a poor source of n-3 PUFA (Surai and Sparks 2001). Thus, the nutritional quality of egg can still be improved by enhancing levels of antioxidants (vitamin E, carotenoids) and n-3 fatty acids such as docosahexaenoic acid (DHA). This would not only increase the stability of PUFA during egg storage and cooking, but also avoid off-taste, thus giving an improved antioxidant and n-3 status to people consuming these eggs. An enriched egg can be obtained by modifying the hen's diet with a feed rich in PUFA like DHA and eicosapentaenoic acid (EPA) or precursors necessary for their synthesis like linolenic acid. Reports are present wherein hens were fed with flaxseed/linseed which contain linolenic acid – precursors for PUFA synthesis (Ferrier et al. 1995; Beynen 2004). This would aid in enriching the egg's yolk. The ALA (alpha linolenic acid) is converted into EPA and DHA by the hen's liver and the synthesized fatty acids are subsequently excreted with the egg yolk (Fig. 2). Humans hardly convert ALA to DHA and recent studies have demonstrated that even if ALA gets converted to EPA or DHA, the conversion rate is very slow, thereby making EPA and DHA to be regarded as very essential (Burdge and Calder 2005). So flaxseed in itself is not a source of DHA, but hens do convert ALA to DHA and deposit it in the egg (Jiang et al. 1991).

The n-3 enriched egg does not show much change in the cooking characteristics (emulsification capacity, hardiness and springiness of sponge cakes) and sensory quality though few people have detected certain off flavours wherein egg was found to have fishy taint (Surai and Sparks 2001). This fishy odour could be suppressed by use of a combination of antioxidants in the hen's diet. Also, the eggs enriched with n-3 PUFA have shown no alteration in the fatty acid composition during cooking as they show increased resistance to oxidation which could be due to the vitamin enrichment in the yolk (Surai and Sparks 2001).

In another set of experiments by Beynen (2004), hens were fed with groundnut, soyabean and linseed oil. The oil in linseed contained about 60% ALA, soya beans contained about 60% linoleic acid (LA) and groundnut oil was rich in oleic acid but contained less ALA. It was observed that feeding the linseed diet produced higher contents of EPA and DHA. Thus in order to enrich egg yolk with PUFA like EPA and DHA, the linoleic acid content needs to be raised which is a precursor for the synthesis of EPA and DHA. The contents of EPA and DHA in eggs can also be increased by feeding diets containing fish oil to the hens, but this has a negative impact on the palatability of the eggs (Huang et al. 1990).

Ferrier et al. (1995) reported leghorn pullets fed with 0, 10 and 20% ground flaxseed showed a marked progressive increase in n-3 fatty acid content as α linolenic acid (28, 261 and 527 mg/egg) and DHA (51, 81 and 87 mg/egg) but no alteration in the cholesterol concentration of the egg yolk. These n-3 fatty acid enriched eggs may serve as possible alternative to fish for these fatty acids and may have health benefits.

Consumption of these eggs have shown various health benefits like decreased plasma triglyceride concentration, lowered systolic and diastolic blood pressures, platelet aggregation and also reduction in total plasma cholesterol level (Surai and Sparks 2001).

Consumer acceptance and regulatory aspects of meat based functional foods

Developing and marketing novel functional meat or meat ingredients incorporated products are unconventional approaches and consumers in many countries may not

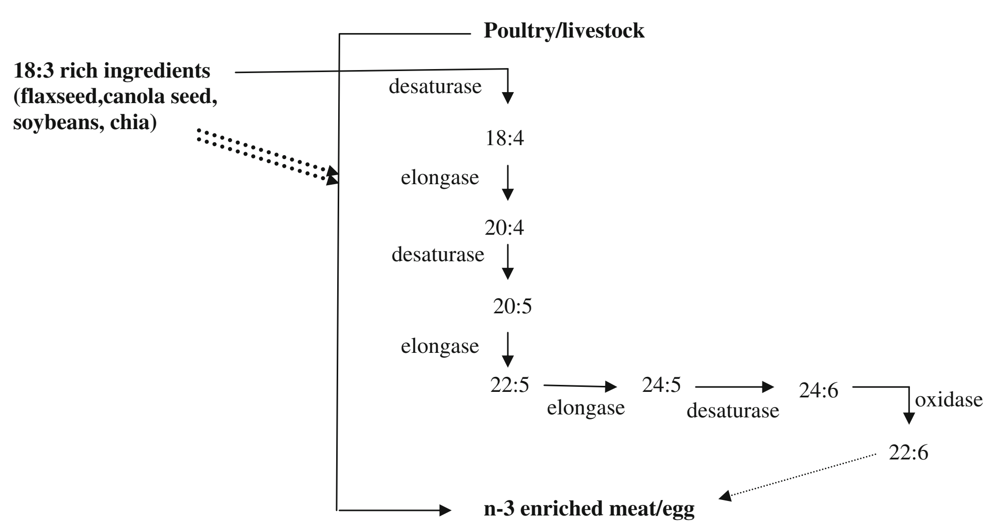

Fig. 2 Enrichment of PUFA in meat or egg (indirect method of improving nutritional and functional significance

consider these products like the way they treat milk and dairy products. This warrants further studies to demonstrate the clear benefits of meat/meat ingredients when modified or incorporated into cereal based products providing awareness to consumers about the physiological benefits they can derive from such products. To many consumers, despite the desirable elevation of nutritional value of food, enrichment with fish oil may negatively impact sensory properties of food due to unacceptable fishy flavour of added fish oil. However, purification technologies (deacidification, bleaching, deodorization, winterization and/or molecular distillation and finally addition of antioxidants) have emerged to remove most of the unpleasant fishy flavour (Kolanowski and Laufenberg 2006). In studies based on meat/meat ingredients, sensory and physicochemical quality of products as affected by meat or meat ingredients also need to be established. Although some reports suggest that many ingredients can be used as functional agents in meat based products (Fernandez et al. 2005), further research is needed to establish the interaction that take place in the food matrix between the meat/meat ingredients and other constituents of the product. This would be very vital to establish its suitability for large scale production.

However, to produce successful products with these ingredients, technologies must be developed to increase their stability and decrease their flavor impact on muscle foods. In addition, many regulatory hurdles must be overcome for the commercial production of meats with added nutrients. These include redefinition of standard of identities and policies that allow front of the package nutritional claims. Without these regulatory changes, production of healthier meat products cannot become a reality since these products would not have a competitive advantage over unfortified meats.

In Japan during 1991, the Ministry of Health introduced rules for approval of a specific health-related food category called FOSHU (Food for Specified Health Uses) which included the establishment of specific health claims for this type of food (Siro et al. 2008). The FOSHU symbol displayed on the food denotes function is superior compared to taste. According to FOSHU regulations, the following documentation needs to be submitted regarding the product.

- a sample of the entire package including labels and health claims:
- documentation that demonstrates the clinical and nutritional proof of the product and/or its functional components aimed at the maintenance of health;
- documentation that demonstrates clinical and nutritional proof of the intake amount of the product and/or its functional component;
- documentation concerning the safety of the product and its functional component, including additional human studies regarding the eating experience;
- documentation concerning the stability of the product and its functional component;
- documentation of the physical and biological characteristics of the product and its functional component;
- details of methods of qualitative and quantitative analytical determination of its functional component, and the analytical results regarding the components of the product;
- a report describing the analysis of the designated nutrient constituents and the product's energy content;
- a statement of the method and equipment used in the food's production, and an explanation of the quality control system.

Consumer trust and food safety have become a central issue in the food chain. Despite the abundant rise of information through labeling, traceability systems and quality assurance schemes, the effect on consumer trust in meat as a safe and wholesome product is only limited.

Among the most important factors influencing the changes in consumer demand for meat and meat products (USDA/ERS 2002) are:

(1) health concerns- increased health concerns have resulted in a shift away from high-fat, high-protein diets to a trend of more fresh vegetables and fruits.
(2) socio- demographic characteristics- various socio-demographic determinants influence the consumer's demand like – [a] income: an estimated 10% increase in income is associated with a 0.7% increase in demand for ready-to-eat meals, especially meat products (USDA/ERS 2002); [b] age - older consumers tend to make more frequent purchases of ground beef and selected leaner ground beef than younger consumers; [c] ethnicity—ethnically diverse customers will have varied demands for newer meat products; [d] convenience—ready to eat meat products are gaining greater demand as it is becoming mandatory to cater to today's time-hungry consumers; [e] change in distribution – today consumers preference in purchasing meat has shifted from traditional to less traditional outlets like warehouse club stores, super centers, mass merchandisers, drugstores and mail order outlets; [f] change in relative prices—domestic markets are affected by prices of competing products, as well as the socio-economic changes occurring in the economy at large.

The development and commerce of the products is a rather complex process. According to (Ioannis and Maria 2005), in order to develop and market a functional ingredient/food, certain criterias need to be followed- (i) the novelty of raw materials, processes employed, as well as the potential use in the diet have yet to be examined. (ii) The safety of novel ingredients and processes has to be assessed before such foods are released in the market. (iii) The benefits and risks to individuals and populations must be weighed carefully when considering the widespread use of physiologically-active functional foods. (iv) The claimed benefits attributed to a product should be justified by reference to appropriate studies. For example- giving the impression that n-3 fatty acid-fortified white bread can adequately substitute for oily fish consumption, or that fiber-enriched soft drinks can substitute a diet rich in naturally-occurring dietary fiber, is rather confusing and undermines attempts to encourage the consumption of oily fish, fruits, vegetables, and wholegrain foods. Care is also required to avoid excessive intakes of other components (e.g., iron, vitamin D, and folic acid), as a continuously growing number of products get enriched, (v) The benefits of the foods should be effectively and clearly communicated to the consumer. Health claims must be clearly supported by sound scientific evidence by conducting clinical studies on people as well, in order to guarantee the safety of products and substantiate the functionality of active components, (vi) Claimed benefits must be real, and their taste and convenience must not be compromised.

The merit of such products can be appreciated only by educated consumers who must also be able to afford them. The regulations governing the scientific evidence required to support claims must protect the consumer while not stifling innovation. It will be difficult to achieve a regulatory formula that pleases everyone, but the consumers' rights must have a priority over the other involved issues (Ioannis and Maria 2005).

There is an estimated 30% increase in major health problems, mainly due to the growing ratio of the aging population, increase in childhood obesity incidents and diseases attributed to irregular dietary habits (Ioannis and Maria 2005). Although no single functional food can erase these effects, food products with genuine health benefits can prevent incidences of such ill effects. With the world food consumption transiting from traditional foods and herbal remedies to designer healthful functional foods/ nutraceuticals with guaranteed health effects, such an approach would lead to a significant increase in the utilization of meat incorporated food.

Conclusions

Development of healthier meat and meat product has become a useful approach for specific applications with health benefits of great importance at a population level. But marketing these products and convincing the consumers is an even more challenging task. Product development efforts have resulted in more failures than successes. The development and commerce of these products are rather complex, expensive and risky. The success of a product involves coordinated efforts between various disciplines especially nutritionists, epidemiology, food technologists, natural product chemists and others. Also, the legislative aspects, sensory assessment and supermarket simulation studies play a vital role. Finally, the success or failure of the functional food is dependent on salient features of the product, its commercial viability and, on the nature, extent and management of collaboration between related disciplines.

References

Alonso BO, Lorencio FG, Barbudo CH, Navarro IB (2006) Nutritional approach for designing meat-based functional food products with nuts. Crit Rev Food Sci Nutr 46:537–542

Anon (2000) Supplement: Why colour foods? Colouring food products with roche carotenoids. The J Food Technol Afr 5:43–47

Arihara K (2006) Strategies for designing novel functional meat products. Meat Sci 74:219–229

Arihara K, Nakashima Y, Ishikawa S, Itoh M (2004) Antihypertensive activities generated from porcine skeletal muscle proteins by lactic acid bacteria. In: Abstracts of 50th international congress of meat science and technology (p. 236), 8–13 August, Helsinki, Finland

Awad AB, Fink CS (2000) Phytosterols as anticancer dietary components: evidence and mechanism of action. J Nutr 130:2127–2130

Benjakul S, Visessanguan W, Phatchrat S, Tanaka M (2003) Chitosan affects transglutaminase-induced surimi gelation. J Food Biochem 27:53–66

Berdague JL, Monteil P, Montel MC, Talon R (1993) Effects of starter cultures on the formation of flavor in dry sausage. Meat Sci 35:275–287

Beynen AC (2004) Fatty acid composition of eggs produced by hens fed diets containing groundnut, soya bean or linseed. Neth J Agric Sci 52:3–10

Bhaskar N, Miyashita K, Hosokawa M (2006) Physiological effects of eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA)—a review. Food Rev Int 22:291–307

Bhaskar N, Chandini SK, Sashima T, Maeda H, Hosokawa M, Miyashita K (2008) Composition, functionality and potential applications of seaweed lipids. In: Hou CT, Shaw J-F (eds) Biocatalysis and bioenergy. John Wiley & Sons, Inc. pp 463–490.

Blandino A, Al-Aseeri ME, Pandiella SS, Cantero D, Webb C (2003) Cereal-based fermented foods and beverages. Food Res Int 36:527–543

Bobek P, Galbavy S, Mariassyova M (2000) Effect of inuline on nutritional hypercholesterolemia and chemically induced precancerous lesions on rat colon. Bull Prot Vyskumu 39:213–221

Bokura H, Kobayashi S (2003) Chitosan decreases total cholesterol in women: a randomized, double blind, placebo-controlled trial. Eur J Clin Nutr 57:721–725

Borderıas AJ, Sanchez-Alonso I, Perez-Mateos M (2005) New applications of fibres in foods: addition to fishery products. Trends Food Sci Technol 16:458–465

Burdge GC, Calder PC (2005) Conversion of α-linolenic acid to long-chain polyunsaturated fatty acids in human adults. Reprod Nutr Dev 45:581–597

Bzducha A, Wolosiak R (2006) Synergistic effect of antioxidant activity of casein and its enzymatic hydrolysate in combination with ascorbic acid and β-carotene in model oxidation systems. Acta Sci Pol Technol Aliment 5:113–133

Cencic A, Chingwaru W (2010) The role of functional foods, nutraceuticals, and food supplements in intestinal health. Nutr 2:611–625

Chew BP, Park JS, Wong MW, Wong TS (1999) A comparison of the anticancer activities of dietary β- carotene, canthaxanthin and astaxanthin in mice in vivo. Antican Res 19:1849–1853

Chizzolini R, Zanardi E, Dorigoni V, Ghidini S (1999) Calorific value and cholesterol content of normal and low-fat meat and meat products. Trends Food Sci Technol 10:119–128

Colmenero FJ (2007) Healthier lipid formulation approaches in meat based functional foods. Technological options for replacement of meat fats by non-meat fats. Trends Food Sci Technol 18:567–578

Coronado SA, Trout GT, Dunshea FR, Shah NP (2002) Antioxidant effects of rosemary extract and whey powder on the oxidative stability of wiener sausages during 10 months frozen storage. Meat Sci 62:217–224

Crittenden RG, Playne MJ (1996) Production, properties and applications of food- grade oligosaccharides. Trends Food Sci Technol 71:353–361

Day L, Seymour RB, Pitts KF, Izabela K, Lundin L (2009) Incorporation of Functional ingredients into foods. Trends Food Sci Technol 20:388–395

De Vuyst L (2000) Technology aspects related to the application of functional starter cultures. Food Technol Biotech 38:105–112

Decker EA, Livisay SA, Zhou S (2000) Mechanisms of endogenous skeletal muscle antioxidants: chemical and physical aspects. In: Decker EA, Faustman C, Lopez-Bolte C (eds) Antioxidants in muscle foods. Wiley- Interscience, New York, pp 25–60

Desmond E (2006) Reducing salt: a challenge for the meat industry. Meat Sci 74:188–196

Desmond EM, Troy DJ, Buckley DJ (1998) The effects of tapioca starch, oat fibre and whey protein on the physical and sensory properties on low-fat beef burgers. LWT Food Sci Technol 31:653–657

Djordjevic D, McClements DJ, Decker EA (2004) Oxidative stability of whey protein-stabilized oil-in-water emulsions at pH 3: potential u-3 fatty acid delivery systems (part B). J Food Sci 69:C356–C362

Englender C (2000) Symptom reduction in irritable bowel syndrome with predigested fish protein supplement. Townsend Lett 205 (206):60–64

Fernandez JM, Fernandez J, Sayas E, Perez JA (2005) Meat products as functional foods: a review. J Food Sci 70:R37–R43

Ferrari CKB (2004) Functional foods, herbs and nutraceuticals: towards biochemical mechanisms of healthy aging. Biogeron 5:275–289

Ferrier KL, Caston LJ, Leeson S, Squires J, Weaver BJ, Holub BJ (1995) α – Linolenic acid – and docosahexaenoic acid- enriched eggs from hens fed flaxseed: influence on blood lipids and platelet phospholipid fatty acids in humans. Am Soc Clin Nutr 62:81–86

Fitzgerald AJ, Rai PS, Marchbank T, Taylor GW, Ghosh S, Ritz BW, Playford RJ (2005) Reparative properties of a commercial fish protein hydrolysate preparation. Gut 54:775–781

Gallant S, Semyonova M, Yuneva M (2000) Carnosine as a potential anti-senescence drug. Biochem Moscow 65:866–868

Garg ML, Wood LG, Singh H, Moughan PJ (2006) Means of delivering recommended levels of long chain n-3 polyunsaturated fatty acids in human diets. J Food Sci 71:R66–R71

Gimeno O, Astiasaran I, Bello J (2001) Calcium ascorbate as a potential partial substitute for NaCl in dry fermented sausages: effect on color, texture and hygienic quality at different concentrations. Meat Sci 57:23–29

Guerin M, Huntley ME, Olaizola M (2003) Haematococcus astaxanthin: applications for human health and nutrition. Trends Biotechnol 21:210–216

Halsted CH (2003) Dietary supplements and functional foods: 2 sides of a coin? Am J Clin Nutr 77:1001–1007

Health Canada (1998) Nutraceuticals/Functional foods and health claim on food final policy. http://www.hc-sc.gc.ca/fn-an/label-etiquet/claims-reclam/nutra-funct_foods-nutra-fonct_aliment-eng.php; last accessed on May 25, 2011.

Holzapfel WH, Geisen R, Schillinger U (1995) Biological preservation of foods with reference to protective cultures, bacteriocins and food-grade enzymes. Int J Food Microbiol 24:343–362

Huang Z, Leibovitz H, Lee CM, Millar R (1990) Effect of dietary fish oil on omega-3 fatty acid levels in chicken eggs and thigh flesh. J Agric Food Chem 38:743–747

Hur SJ, Ye BW, Lee JL, Ha YL, Park GB, Joo ST (2004) Effects of conjugated linoleic acid on color and lipid oxidation of beef patties during cold storage. Meat Sci 66:771–775

Ioannis SA, Maria VHK (2005) Functional foods: a survey of health claims, pros and cons, and current legislation. Crit Rev Food Sci Nutr 45:385–404

Jacobsen C, Bruni LM, Nielsen NS, Meyer AS (2008) Antioxidant strategies for preventing oxidative flavour deterioration of foods enriched with n-3 polyunsaturated lipids: a comparative evaluation. Trends Food Sci Technol 19:76–93

Jeun HL, Yuan HL, Chun CK (2002) Effect of dietary fish oil on fatty acid composition, lipid oxidation and sensory property of chicken frankfurters during storage. Meat Sci 60:161–167

Jiang Z, Ahn DU, Sim J (1991) Effect of feeding flax and two types of sunflower seeds on fatty acid compositions of yolk lipid classes. Poultry Sci 41:2467–2475

Jimenez-Colmenero F, Carballo J, Cofrades S (2001) Healthier meat and meat products: their role as functional foods. Meat Sci 59:5–13

Jo C, Lee JW, Lee KH, Byun MW (2001) Quality properties of pork sausage prepared with water-soluble chitosan oligomer. Meat Sci 59:369–375

Jose A, Regueiro G, Arnau J, Díaz I (2011) Use of phytosterols in meat and meat products: an approach. http://www.q-porkchains.org/news/newsletters/no_8/phytosterols.aspx; last accessed on March 25, 2011.

Kamil J, Jeon YJ, Shahidi F (2002) Antioxidative activity of chitosans of different viscosity in cooked comminuted flesh of herring (*Clupea harengus*). Food Chem 79:69–77

Kim SK, Mendis E (2006) Bioactive compounds from marine processing byproducts – a review. Food Res Int 39:383–393

Kolanowski W, Laufenberg G (2006) Enrichment of food products with polyunsaturated fatty acids by fish oil addition. Eur Food Res Technol 222:472–477

Korhonen H, Anne PL, Pirjo R, Tuomo T (1998) Impact of processing on bioactive proteins and peptides. Trends Food Sci Technol 9:307–319

Lee S, Faustman C, Djordjevic D, Faraji H, Decker EA (2006) Effect of antioxidants on stabilization of meat products fortified with n-3 fatty acids. Meat Sci 72:18–24

Leroy F, De Vuyst L (2003) Exploring a functional starter culture. New Food 2:35–40

Leroy F, De Vuyst L (2004) Lactic acid bacteria as functional starter cultures for the food industry. Trends Food Sci Technol 15:67–78
Liaset B, Madsen L, Hao C, Mellgren G, Marschall H, Hallenborg P, Espe M, Froyland L, Kristiansen K (2009) Fish protein hydrolysate elevates plasma bile acids and reduces visceral adipose tissue mass in rats. Biochem Biophys Acta—Mol Cell Biol Lipids 1791:254–262
Lin KW, Chao JY (2001) Quality characteristics of reduced fat Chinese-style sausage as related to chitosan's molecular weight. Meat Sci 59:343–351
Lopez-Caballero ME, Gomez-Guillen MC, Perez-Mateos M, Montero P (2005a) A chitosan-gelatin blend as a coating for fish patties. Food Hydrocol 19:303–311
Lopez-Caballero ME, Gomez-Guillen MC, Perez-Mateos M, Montero P (2005b) A functional chitosan-enriched fish sausage treated by high pressure. J Food Sci 70:166–171
Lucke FK (1998) Fermented sausages. In: Wood BJB (ed) Microbiology of fermented foods. Blackie Academic and Professional, London, pp 441–483
Lucke FK (2000) Utilization of microbes to process and preserve meat. Meat Sci 56:105–115
Maezaki Y, Tsuji K, Nakagawa Y, Kawai Y, Akimoto M, Tsugita T (1993) Hypocholesterolemic effect of chitosan in adult males. Biosci Biotechnol Biochem 57:1439–1444
Mansour EH, Khalil AH (1999) Characteristics of low-fat beef burgers as influenced by various types of wheat fibres. J Sci Food Agric 79:493–498
Marchbank T, Limdi JK, Mahmood A, Elia G, Playford RJ (2008) Clinical trial: protective effect of a commercial fish protein hydrolysate against indomethacin (NSAID)-induced small intestinal injury. Alimentar Pharmacol Ther 28:799–804
Marchbank T, Elia G, Playford RJ (2009) Intestinal protective effect of a commercial fish protein hydrolysate preparation. Regul Pept 155(1–3):105–109
Miguel L, Carlos MT, Irene L, Peter T, Jose R (1984) Effect of histidine, cysteine, glutathione or beef on iron absorption in humans. Am Inst Nutr 114:217–223
Mital BK, Garg SK (1995) Anticarcinogenic, hypocholesterolemic, and antagonistic activities of *Lactobacillus acidophilus*. Crit Rev Microbiol 21:175–214
Modi VK, Yashoda KP, Bhaskar N, Mahendrakar NS (2009) Effect of carrageenan and oat flour on storage characteristics of fried mutton kofta. J Food Proc Pres 33:763–776
Mortensen A, Skibsted LH (2000) Antioxidant activity of carotenoids in muscle foods. In: Decker EA, Faustman C, Lopez-Bote C (eds) Antioxidants in muscle foods. Wiley-Interscience, New York, pp 61–84
Morton S (1994) Morton lite salt® mixture. The best alternative to salt. Product Brochure. http://www.mortonsalt.com/products/foodsalts/Lite_Salt.htm. Last accessed on 30th Dec 2010.
Naga ME, Prabhakar K, Reddy PM (2009) Low fat meat products - an overview. Veterinary World 2:364–366
Neklyudov AD, Ivankin AN, Berdutina AV (2000) Properties and uses of protein hydrolysates (Review). Appl Biochem Microbiol 36:452–459
NIIR Board (2004) Food colours, flavours and additives technology handbook. http://www.niir.org/books/book/food-colours-flavours-additives-technology-handbook-niir-boa. Last accessed on 30th Dec 2010.
Nimish MS, Bhaskar N, Hosokawa M, Miyashita K (2011) Marine nutraceuticals: sources, recovery and effective utilization. In: Haghi AK (ed) Adv Food Sci Technol. Novo Publ, NY, USA, pp 1–18
Normen L, Bryngelsson S, Johnsson M, Evheden P, Ellegard L, Brants H, Andersson H, Dutts P (2002) The phytosterol content of some cereal foods commonly consumed in Sweden and in the Netherlands. J Food Comp Anal 15:693–704
Peter JJH (2009) Phytosterols as functional food ingredients: linkages to cardiovascular disease and cancer. Curr Opin Clin Nutr Met Care 12:147–151
Prabhashankar P, Ganesan P, Bhaskar N (2009) Influence of Indian seaweed (*Sargassum marginanum*) as an ingredient on quality, biofunctional and microstructure characteristics of pasta. Food Sci Technol 15:471–479
Prasad B, Rashmi MD, Yashoda KP, Modi VK (2011) Effect of casein and oat flour on physicochemical, Oxidative processes, sensory properties and Storage stability of cooked chicken *kofta*. J Food Proc Pres 33:359–368
Prates JAM, Mateus CMRP (2002) Functional foods from animal sources and their physiologically active components. Rev Med Vet 3:155–160
Rosenfeldt FL, Pepe S, Linnane A, Nagley P, Rowland M, Ou R, Marasco S, Lyon W, Esmore D (2002) Coenzyme Q10 protects the aging heart against oxdative stress. Studies in rats, human tissues and patients. Ann NY Acad Sci 959:355–359
Ruusunen M, Puolanne E (2005) Reducing sodium intake from meat products. Meat Sci 70:531–541
Ruusunen M, Vainionpaa J, Lyly M, Lahteenmaki L, Niemisto M, Ahvenainen R, Puolanne E (2005) Reducing the sodium content in meat products: the effect of the formulation in low-sodium ground meat patties. Meat Sci 69:53–60
Sadler MJ (2004) Meat alternatives - market developments and health benefits. Trends Food Sci Technol 15:250–260
Sameshima T, Magome C, Takeshita K, Arihara K, Itoh M, Kondo Y (1998) Effect of intestinal Lactobacillus starter cultures on the behaviour of *Staphylococcus aureus* in fermented sausage. Int J Food Microbiol 41:1–7
Shahidi F, Arachchi JKV, Jeon YJ (1999) Food applications of chitin and chitosans. Trends Food Sci Technol 10:37–51
Siro I, Kapolna E, Kapolna B, Lugasi A (2008) Functional food. Product development, marketing and consumer acceptance—a review. Appetite 51:456–467
Suh JH, Shigeno ET, Morrow JD, Cox B, Rocha AE, Frei B, Hagen TM (2001) Oxidative stress in the aging rat.heart is reversed by dietary supplementation with (R)-α-lipoic acid. Faseb J 15:700–706
Surai PF, Sparks NHC (2001) Designer eggs: from improvement of egg composition to functional food. Trends Food Sci Technol 12:7–16
Taşan M, Bilgin B, Geçgel U, Demirci AŞ (2006) Phytosterols as functional food ingredients. J Tekirdag Agric Fac 3:153–159
Terasaki M, Hirose A, Bhaskar N, Baba Y, Kawagoe C, Yasui H, Saga N, Hosokawa M, Miyashita K (2009) Evaluation of recoverable functional lipid components of several brown seaweeds (*Phaeophyta*) from Japan with special reference to fucoxanthin and fucosterol contents. J Phycol 45:974–980
Tharanthan RN (2005) Starch-value addition by modification. Crit Rev Food Sci Nutr 45:371–384
Ulu H (2004) Effect of wheat flour, whey protein concentrate and soya protein isolate on oxidative processes and textural properties of cooked meatballs. Food Chem 87:523–529
USDA/Economic Research Service (2002) Changing consumer demands create opportunities for U.S. food system. Food Rev 25:19–22
Valsta LM, Tapanainen H, Mannisto S (2005) Meat fats in nutrition. Meat Sci 70:525–530
Williams P (2007) Nutritional composition of red meat. Nutr Diet 64: S116–S119
Yilmaz I (2004) Effects of rye bran addition on fatty acid composition and quality characteristics of low-fat meatballs. Meat Sci 67:245–249

Zhou S, Decker EA (1999) Ability of carnosine and other skeletal muscle components to quench unsaturated aldehydic lipid oxidation products. J Agric Food Chem 47:51–55

Zotte AD (2002) Perception of rabbit meat quality and major factors influencing the rabbit carcass and meat quality. Livest Prod Sci 75:11–32

Zotte AD, Szendro Z (2011) The role of rabbit meat as a functional food. Meat Sci 88:319–331

Zotte AD, Berzaghi P, Serva L, Verdiglione R (2006) Comparison of oven drying with permeable film in substitution to freeze-drying in rabbit meat submitted to chemical analysis. Acta Agric Kapos 10:245–249