

Dietary fiber enriched meat products: A review

Abstract

Meat and meat products are important sources of high biological value proteins, fat soluble vitamins, minerals, trace elements and other nutritional compounds. Increased consumer's demand for convenience and easily available foods such as meat products and their byproducts have the changed due to various socioeconomic factors in recent years. Processing technology in meat industry introduce many functional compounds beneficial to human health but most of those foods are rich in fat, added salts but deficient in complex carbohydrates like dietary fiber and pose a health hazard that somehow is proved to be a predisposing factor for cardiovascular diseases, colon cancer, obesity including diabetes mellitus. Nutritional disease shows concern in present generation due to consciousness among consumers about their nutrition and well being. Therefore an increase in dietary fiber inclusion in daily diet has been recommended. For adults, the recommended acceptable intakes of dietary fiber are 28–36 g/day, 70–80 % of which must be insoluble fiber. The insoluble fraction of dietary fiber functions in intestinal regulation whereas soluble fiber helps in decrease in cholesterol level and absorption of intestinal glucose. Dietary fibers addition in meat products from various sources such as fruits and vegetables would help to enhance their desirability. Dietary fiber sources are generally agricultural byproducts that are comparatively cheap and incorporation in meat products reduces its overall cost.

Key words Meat products, Biological value, Dietary fiber, Diabetes mellitus, Soluble fiber

Introduction

Food has been used to improve the health in people, awareness and various health aspects being used to innovate and modify foods (Fergus 2004). Approach in promising cared health sector is low to produce effective food products as benefit healthy programme (Decker and Park 2010). Meat is a potential source of nutrients like proteins and fat soluble vitamins and minerals with higher degree of bioavailability as compared to other sources (Chan 2004; Biesalski 2005) many compounds are generated during processing of meat and meat products which are beneficial to the human health (Saiga *et al.*, 2003; Vercruysse *et al.*, 2005) and accepting a relationship between nutrition and health gave a innovative concept of functional foods including meat products (Bhat and Bhat 2011) which contains health benefit ingredients (Roberfroid 2002). Research of epidemiology showed relationship of diet deficient in dietary

fiber and chronic diseases including colon cancer, obesity and cardiovascular diseases (WHO/FAO 2003). The relation of energy dense foods and various diseases stresses mainly on components considered as marker of healthy food (Best 1991). American Dietetic Association have recommended fiber intake in range of 25 to 30 g/day and 3:1 insoluble/soluble fibre ratio for adults. Meat is a nutritious, cheap and easily available food, besides water fat and protein are important components of meat. Meat and meat products contains high amount of fat and protein but deficient in dietary fiber (Sanchez-Zapata et al., 2010) and its fortification in meat products have been focused on health point of view. Fiber are important ingredient in meat products on the healthy point of view. The fibers alone or combined with other products such as meat for low fat content such as ground and restructured products (Desmond *et al.*, 1998) and meat emulsions (Claus and Hunt 1991) have been studied.

1. Meat

The term meat refers to the muscle of warm blooded terrestrial four legged animals, the chief ones being cattle and sheep. Meat also includes the glands and organs of these animals. Meat products also includes many of the by products from animal slaughter, such as animal gut used for sausage casings, the fat from the meat used in the manufacture of lard, gelatin and others. The annual consumption of meat of any countries depends upon its economic status, affluent countries consuming more than others. The average per capita consumption of meat is 67 kg per annum in US which is more than of many countries. The per capita consumption of meat in India is of order of 1.2 kg per annum. Meat and meat products are generally recognized as good sources of high biological value proteins, fat soluble vitamins, minerals, trace elements and bioactive compounds. Meat is frequently associated with a negative health image due to its “high” fat content and in the case of red meat is seen as a cancer-promoting food. Therefore a low meat intake, especially red meat is recommended to avoid the risk of cancer, obesity and metabolic syndrome (Biesalski, 2005). However this discussion overlooks the fact, that meat is an important source for some micronutrients such as trace elements and vitamins, which are either not present in plant derived food or have a poor bioavailability. In addition, meat as a protein-rich and carbohydrate-low product contributes to a low glycemic index, which is assumed to be beneficial with respect to obesity, diabetes development and cancer (Biesalski, 2005).

1.1. Protein

A typical muscle consists of around 75 % water, 20 % protein, 3 % fat and 2 % soluble nonprotein substances. Proteins are the major component of the dry matter of lean meat (Briggs & Schweigert, 1990). Nine of the amino acids present in proteins are essential (or semi-essential) because the human body cannot synthesize them from other compounds, and therefore must taken them up from food. Therefore, the requirement for dietary protein consists of two components; (a) a requirement for the nutritionally essential amino acids, and (b) the need to meet the requirement for non-specific nitrogen in order to supply the nitrogen necessary for synthesis of the nutritionally not essential amino acids and other physiologically important nitrogen containing compounds (nucleic acids, creatine, porphyrins) (Pellett & Young, 1990). Meat contains generally high levels of the major essential amino acids, lysine, total sulfur amino acids, threonine and tryptophane (Pellett & Young, 1990). Protein quality is usually defined according to the amino acid pattern of egg protein, which is regarded as optimal. It is not surprising that animal proteins, such as meat, milk and cheese tend to be of a higher protein quality than plant proteins. Animal proteins have a better digestibility compared to plant proteins. This can be explained to some extent with the fact that plant proteins are mostly embedded into polysaccharide matrices (cell walls) where they cannot be reached by the proteolytical enzymes. A healthy nutrition requires a balanced mix of different food proteins. By combining plant and animal food the nutritional quality of the protein can be increased because of the complementing effect.

1.2. Fat

Fat is the richest dietary source of energy and supplies essential nutrients such as essential fatty acids as well as precursors of compounds that regulate a number of physiological functions (e.g. prostaglandins) and helps to absorb fat-soluble vitamins (A, D, E and K). Further fat has a decisive relevance as the most compact energy store of the body, as fixation as well as a protection of the organs and as source of fatty acids which again act as structural element of cell membranes. Fat also provides palatability and flavor to food. In the right proportions it is therefore an essential component of any balanced diet, and hence the degree of fat reduction must not only take into account sensory or technological factors but it must also be such as to avoid loss of nutritional benefits (Colmenero, 2000). Meat is looked at very critically because of its fat content being generally included under the heading of fatty foods. The fat in animals is

mainly found in their fatty tissue and is distinguished between depot fat (largely subcutaneous fatty tissue), intermuscular and intramuscular fat. The last of these is called marbling. The amount of intermuscular and depot fat present in a meat cut varies, depending on the fat excretion of the animal and how the cut has been trimmed (Seuss *et al.*, 1988). Contrary to the widespread belief that animal fat is mainly composed of saturated fatty acids (SFA), roughly half of the fatty acids in meat are unsaturated. Meat lipids usually contain less than 50 % SFA, and up to 70 % (beef 50-52 %, pork 55-57 %, lamb 50-52 % and chicken 70 %) unsaturated fatty acids (Romans *et al.*, 1994).

1.3.Minerals and trace elements

Beside the macronutrients protein and fat, meat contains micronutrients (minerals and vitamins) which are involved in essential metabolic processes. Meat, fish, poultry and offal are the only foods that contain the better available heme iron besides the inorganic iron (non-heme iron) (Latunde-Dada & Neale, 1986). Meat, fish, poultry and offal are the only foods that contain the better available heme iron besides the inorganic iron (non-heme iron) (Latunde-Dada & Neale, 1986). Meat is not only an important source of available iron, but also of zinc. It is well known that absorption of dietary zinc from animal protein based meals is higher compared to wholegrain cereal based meals (King & Turnland, 1989). The trace element selenium (Se) is a crucial nutrient for human health. It is a component of a number of important selenoproteins including enzymes required for such functions as antioxidative defense, reduction of inflammation, thyroid hormone production, DNA synthesis, fertility and reproduction (Raymann, 2000).

1.4.Vitamins

Vitamins are a complex group of organic compounds that are generally present in small quantities in foodstuffs. Vitamins are important as cofactors in enzymatic processes and also possess hormonal activity. Traditionally, vitamins have been classified on the basis of their solubility in either lipid or aqueous solvents, and they are therefore broadly divided into fat and water-soluble vitamin categories (McDowell, 2000; Cheeke, 2005). Fat-soluble vitamins tend to be mainly stored in the liver and adipose tissues of animals, in association with stored fat, and they are not readily excreted. Water-soluble vitamins, on the other hand, tend to be stored to a far lesser extent in the body. The vitamins contained in animal and human diets are predominantly derived from either plant or microbial synthesis. Animal cells maintain the ability for de novo

synthesis of some vitamins, such as vitamin D and, depending on the species involved, niacin and ascorbate, as well as the ability to convert precursors (provitamins) to their active form. Additionally, commensal microorganisms in both the ruminant and non-ruminant digestive tract can serve as source of vitamins, such as vitamin K and the water-soluble B-complex vitamins (Sahlin & House, 2006). Meat has long been recognized as a good source of B vitamins for human nutrition. Meat, especially pork has long been recognized as a good source of thiamine (Briggs & Schweigert, 1990).

2. Dietary fiber

Most of meat foods are rich in fat and protein but deficient in complex carbohydrates like dietary fiber (Sanchez- Zapata *et al.*, 2010) and So incorporation of dietary fibers from different sources in meat products would help to enhance their desirability. Dietary fiber sources are generally agricultural byproducts that are comparatively cheap and incorporation in meat products reduces its overall cost. The term dietary fiber was first used in 1953 by Eben Hipsley to describe the unavailable carbohydrate content in foods, which lowered the rates of pregnancy toxemia (Hipsley, 1953). Previously the analytical term ‘crude fiber’ was used for components that escaped acid and alkali extractions (Trowell, 1976). Spiller *et al.*, (1978) used the term ‘plantix’ for fiber and Trowell *et al.*, (1985) defined dietary fiber as “sum of polysaccharides and lignin not digested by human gastrointestinal tract.” The conflict between what to define as dietary fiber and its analysis has made its definition in classification a little tough for public health agencies and food industries (McCleary, 2008). According to american association of cereal chemists, dietary fiber is the remanant of edible part of plants that escaped digestion and absorption in small intestine (AACC 2001). The components that constitute dietary fiber are listed in the Table 1.

Table1. The components and sources that constitute dietary fiber

Fiber components	Principal groupings	Fiber sources
Non starch polysaccharides and oligosaccharides	Cellulose	Cellulose plants (vegetable, sugar beet, various brans)
	Hemicellulose	Arabinogalactans, β -glucans, arabinoxylans
	Polyfructoses	glucuronoxylans, xyloglucans,
	Gums and mucilages	galactomannans, pectic substances Inulin, oligofructans

		Seed extracts (galactomannans – guar and locust bean gum), tree exudates (gumacacia, gum karaya, gum tragacanth), algal polysaccharides (alginates, agarcarrageenan), psyllium
Carbohydrate analogues	Pectins Resistant starches and maltodextrins Chemical synthesis Enzymatic synthesis	Fruits, vegetables, legumes, potato, sugar beets Various plants such as maize, pea, potato Polydextrose, lactulose, cellulose derivatives Neosugar or short chain, guar hydrolyzate Fructooligosaccharides, levan, xanthan gum, transgalactooligosaccharides, oligofructose, xylooligosaccharide, curdlan
Lignin	Lignin	Woody plants
Substances associated with nonstarch polysaccharides	Waxes, cutin, Suberin	Plant fibers
Animal origin fibers	Chitin, chitosan, collagen, chondroitin	Fungi, yeasts, invertebrates

(Source: Tunland and Meyer, 2002)

2.1. Dietary fiber classifications

Dietary fiber can be classified by many possible ways, such as, on the basis of sources from which they are derived and that can be further categorized into plant polysaccharides, animal polysaccharides or synthetic sources. On the basis of the structure, they can be classified into linear or non linear polysaccharides. But the most widely accepted and used system of classification is on the basis of solubility and/or the fermentation behavior in an in vitro system using an enzyme component which simulates that of human alimentary canal. According to their water solubility, dietary fiber is conventionally classified into insoluble dietary fiber (IDF)/less fermented fiber and soluble dietary fiber (SDF)/well fermented fibers. Insoluble fiber consists of cellulose, part of hemicelluloses and lignin and soluble fiber consists of pentosans, pectins, gums and mucilage (Chawla & Patil, 2010). Welsh *et al.*, (1994) concluded that the whole grains are the major source of insoluble dietary fiber and Van Soest (1976) reported that maximum amount

of hemicellulose in diet is contributed by bran and husks. The classification of dietary fiber based on solubility is shown in Table 2.

Table 2. Classification of dietary fiber based on solubility

Class	Examples
Insoluble	Cellulose
Soluble (only in hot water)	Agars, amylose, aligns, kappa-type carrageenans (in the presence of K ⁺ or Ca ²⁺), gelan, konjac, mannan, locust bean gum, low methoxyl pectins, granular starches and starch derivatives
Soluble (in water at room temperature but insoluble in hot water)	Curdlan, hydroxylpropylcelluloses, hydroxylpropylmethylcelluloses and methylcelluloses
Soluble (in water at room temperature and hot water)	Alginates, amylopectins, carboxymethylcelluloses, dextrans, iota type carrageenans, guar gum, gum Arabic, high methoxyl pectins, polydextrose and xanthan gum

(Source: BeMiller, 2001)

2.1.1. Cellulose

Cellulose is a linear chain of β (1→4) linked glucose monomers and is the structural component of cell walls in green plants and vegetables. It is water insoluble and inert to digestive enzymes in the small intestine. However, it can go through microbial fermentation to a certain degree in the large intestine in turn producing short chain fatty acids. Basically, cellulose can be divided into two groups: Crystalline and amorphous. The crystalline component, which is made up of intra and intermolecular non covalent hydrogen bonds, make cellulose insoluble in water. It is also responsible for its great mechanical strength and resistance to microbial degradation and makes up a large portion of cellulose. On the other hand, the amorphous portion is readily hydrolysed and makes up a little (10–15 %) portion of total cellulose (Aspinall, 1970).

2.1.2. Hemicellulose

It consists of chain of β (1→4) linked glucose monomers similar to that of cellulose but they are smaller in size, usually branched and contain variety of sugar moieties like xylose, mannose and arabinose (Kay, 1982).

2.1.3. Resistant starches (RS)

Any starch not digested in the small intestine is known as resistant starch. It behaves like soluble fiber without sacrificing palatability and mouth feel. RS has been classified into four basic types - Type 1 (RS1) is made up of starch granules surrounded by an indigestible plant matrix. Type 2 (RS2) occurs in its natural form such as in an uncooked potato and high amylose maize. Type 3 (RS3) are crystallized starches made by unique cooking and cooling processes. Type 4 (RS4) is a starch chemically modified by esterification, crosslinking, or transglycosylation and is not found in nature. The cross-linked RS4 is found to elicit a greater glucose lowering effect than the more commonly tested RS2 (Haub *et al.*, 2010).

2.1.4. Lignin

It is a polymer containing the oxygenated phenyl propane units including the coniferyl, sinapyl and p-coumaryl alcohols that have undergone a complex dehydrogenative polymerization (Schubert, 1956). It is very inert in nature and has a greater resistance power than any other naturally occurring polymer (Dhingra *et al.*, 2012).

2.1.5. Pectin

Pectin is a linear polymer of galacturonic acid connected with α (1 $\rightarrow$ 4) bonds. It is a water soluble polysaccharide that bypasses enzymatic digestion of the small intestine but is easily degraded by the microflora of the colon. At commercial level, these are typically used in food applications which require a gelling or a thickening agent. Inside the GI tract, pectin maintains this ability to form a gel or thicken a solution. Due to this gelling behavior, it is linked to many beneficial effects on health including dumping syndrome (Lawaetz *et al.*, 1983), improved cholesterol and lipid metabolism (Brown *et al.*, 1999) and diabetes prevention and control (Jenkins *et al.*, 1977).

3. Technological functionality of dietary fibre

Dietary fibre is complex polysaccharide which show wide range of functionality such as emulsification, fat replacement, gel-forming, cryoprotectant, thickener & stabilizer. These technical functionalities are highly influenced by the physico-chemical properties of dietary fibres, such as water-holding & binding capacity, oil binding capacity, solubility & viscosity which are discussed (Elleuch *et al.*, 2011; Theabaudin *et al.*, 1997).

211 **Table 3: Factors effecting techno functionality properties of dietary fiber**

Factor	Techno-functional properties
Type of fibre	Water holding capacity of soluble fibre is higher than insoluble Flaxseed gum in dairy beverages resulted in better sensory & rheological properties
Particle size	Decrease in hydration with decrease in particle size of wheat bran Increase with reduction in coconut fibre particle size
Molecular weight	High molecular weight β -glucan difficult to dissolve in water even at low concentration of 0.5%
Nature of chain	Highly branched guar gum & pectin more soluble & viscous

212

213 **4. Recommended dietary allowances (RDA) for dietary fiber**

214 The dietary fiber has been recognized as an important part of the complete diet and it is
 215 believed that a fiber intake of 30–40 g/day is desirable. Out of it, half should be derived from
 216 cereal bran and other half from fruits and vegetables (Nayak *et al.*, 2000). The amount of dietary
 217 fiber provided by cereals depends on the source and the degree of processing. For example, the
 218 content of fiber in refined wheat flour is 2.5 g/100 g while in unrefined flour, it is 12 g/100 g
 219 which is around five times higher than former. The insoluble fraction of dietary fiber gets
 220 removed at large during refining process (Rodriguez *et al.*, 2006). The recommendations
 221 regarding the intake of dietary fiber are not same in all countries. The difference is due to the
 222 variable eating habits, lifestyles and the degree of processing of various food products consumed
 223 in different countries (Bemiller, 2004). An average Indian diet contains about 6–8.5 g of crude
 224 fiber (Mehta & Kaur, 1992). Some International Committee recommendations for the total
 225 dietary fiber intake in diet per day has been presented in Table 4.

226 **Table 4. Some International Committee Recommendations regarding RDA for total dietary**
 227 **fiber intake**

Source	Recommendation (g/day)
National Cancer Institute	20–30
USDA and USFDA	38 for men and 26 for women
National Academy of Sciences (USA)	30–38 for men and 21–26 for women
UK Department of Health	18 (expressed as Non starch polysachharide)

German Department of Health	30
-----------------------------	----

(Bemiller 2004)

5. Physiological role and health benefits of dietary fiber

Dietary fiber plays a significant role in prevention of several diseases and maintenance of health. The mechanism by which each fiber exerts a protective action in the body varies with the type and composition of that fiber.

5.1. Dietary fiber as a restraint for prevention of risk of cardiovascular diseases

Dietary fiber acts as a protective agent against cardiovascular diseases. They exert this action by acting as reducing agent of hyperlipidemia and hypocholesterolemia (Kendall *et al.*, 2009). The exact mechanism by which dietary fibers lower serum LDL cholesterol levels is not known. Evidence suggests that they may interfere with lipid and/or bile acid metabolism. Dietary fiber from coconut is rich in uronic acid, glucomannans and galactomannans which are metabolized by microflora of large intestine and produce short chain fatty acids such as acetates, propionate and butyrate that contribute to lowering serum cholesterol levels (Theuwissen & Mensink, 2008). Similarly dietary fiber from other sources such as oat bran, guar gum (Fahrenbach *et al.*, 1965), psyllium (Garvin *et al.*, 1965) have also been found to lower the serum cholesterol levels. Other suggested mechanisms include inhibition of hepatic lipoprotein production and cholesterol synthesis, delayed absorption of macro nutrients leading to increased insulin sensitivity and formation of protective membrane by dietary fibers around lipid droplet that prevent the action of lipase (Mun *et al.*, 2006). It has also been suggested that dietary fiber has a capacity to bind bile acids and metabolites of cholesterol which play an important role in digestion and absorption of lipids in small intestine. This leads to lower serum cholesterol concentration by interrupting enterohepatic circulation (Eastwood, 1992). The fiber polysaccharides affect the absorption of lipids, as they can be strong inhibitors of pancreatic lipase that participates in lipid metabolism (Dunaif & Schneeman, 1981). On the other hand they decrease the level of total cholesterol and low-density lipoproteins in plasma by dilution and excretion of bile acids (Gallaher *et al.*, 1992) and by decreasing absorption of biliary cholesterol (Marlett *et al.*, 1994).

5.2. Improvement in gastrointestinal health

The fiber can bind a large amount of water resulting in an increase in stool weight (Cummings, 1993). Increased stool bulk reduces colonic transit time which prevents constipation and production of carcinogenic and genotoxic compounds (Gibson, 2004). Dietary fiber plays an important role in maintenance of gastrointestinal immunity. In particular, the fermentable fiber diet result in an increased T-cell mitogen response and increased activity of gut associated lymphoid tissue (GALT) (Field *et al.*, 1999). The fermentation of dietary fiber in large intestine by gut microflora results in increased level of short chain fatty acids which are believed to be important for promoting the health of colonic epithelium (Topping & Clifton, 2001). Also, it results in lowering of colonic pH, which inhibits the potentially harmful bacteria and promote the growth of favorable lactic acid microflora (Grasten *et al.*, 2003).

5.3. Role of fiber in preventing cancer

Relationship between dietary fiber and colon cancer, despite its complexity, are quite well documented. Dietary fiber imparts anticarcinogenic and antitumerogenic effects either by reducing the production of carcinogenic substances in colon (Rumney & Rowland, 1995) or by increasing faecal bulk that ultimately decreases effective interactions between intestinal mucosa and cancer risk agents present in faeces (Harris & Ferguson, 1993). Dietary fiber might reduce the risk of colorectal cancer by enhanced fermentation in large intestine leading to productions of high levels of short chain fatty acids (Sharma *et al.*, 2008). The butyric acid is reported to promote cell differentiation and inhibit the production of secondary bile acids by reducing luminal pH resulting in reduction of risk of malignant changes in cell (Potter, 1999).

5.4. Fiber and diabetes mellitus

The risk of Type 2 diabetes mellitus is inversely correlated with intake of diets with high fiber content (Schulze *et al.*, 2004). The reduction in plasma glucose concentration as a result of consumption of various fiber sources may be due to several events. The fiber has ability to lower post-prandial glucose peak, which leads to decreased insulin demands and protects the over exhaustion of the pancreas. The ingested fibers slow gastric emptying by forming a gel matrix as a result of their high water holding capacity (Wursch & Pi-Sunyer, 1997). This gel matrix may thicken small intestinal contents and decrease the contact between food and digestive enzymes (Jenkins *et al.*, 1978). In addition, the fibers could alter the contractile movements in gastro intestinal tracts and thereby decrease the transport of glucose to the absorptive surface (Malkki, 2001).

5.5. Fiber as an effective tool for weight management

A number of researches have also examined the potential of dietary fiber as satiety agent and a contributor to weight management (Sharma *et al.*, 2008). Dietary fiber intake may increase the mobilization and use of fat depots as a direct result of reduction in insulin secretion (Tapsell, 2004). The diets rich in fiber lead to slowing down in gastric emptying resulting in slower rate of nutrient absorption (Brennan, 2005). The high fiber diet also reduces the energy density of overall diet.

6. Dietary fiber addition on meat and meat products

Meat and meat products are generally recognized as good sources of high biological value proteins, fat soluble vitamins, minerals, trace elements and bioactive compounds. Changes in socioeconomic factors in recent years have increased the consumer's preference for ready to eat foods including meat products. The processing of meat and meat products leads to generation of many functional compounds beneficial to human health but most of those foods are rich in fat, added salts but deficient in complex carbohydrates like dietary fiber and pose a health hazard that somehow is proved to be a predisposing factor for cardiovascular diseases, colon cancer, obesity including diabetes mellitus. Processed foods and fast foods have become mainstay of typical diets in modern society. In developing countries like India rapid urbanization, industrialization, globalization as well as increasing number of women workforce have resulted in rapid inclination towards fast foods. Many of these processed foods including meat products lack minimum amounts of dietary fibre. Epidemiological research has demonstrated a relationship between a diet containing an excess of energy-dense foods rich in fat and sugar and the emergence of a range of chronic diseases, including colon cancer, obesity, cardiovascular diseases, and several other disorders (Best, 1991). Various reports have revealed that intake of fibre reduces the risk of such diseases (Johnson and Southgate, 1994). Recent research findings also reveal that a diet high in fibre generally promotes a healthier life style (Kritchevsky, 2000) and fibre intake can be viewed as a marker of healthy diet. According to the American Dietetic Association, the current recommended fibre intakes for adults range from 25 to 30 g/day and the insoluble/soluble fibre ratio should be 3:1. Dietary fibre is a key ingredient widely used nowadays while developing nutritionally designed foods due to its significance in health promotion (Puupponen-Pimia *et al.*, 2002) and technological impact. Meat is a highly nutritious and versatile food. Its principal components, besides water, are proteins and fats, with a

substantial contribution of vitamins and minerals of a high degree of bioavailability. However, meat and meat products can be tailored into more “healthier” form by adding ingredients considered beneficial for health or by eliminating or reducing components that are considered harmful. Fibre is one of the valuable components that can be incorporated in meat products from health point of view. Various types of fibres have been studied either alone or combined with other ingredients for formulation of reduced-fat meat products, mostly ground and restructured products (Mansour & Khalil, 1999) and meat emulsions (Claus & Hunt, 1991). Meat is an important source of all essential nutritional components of our daily diet as it content most of the essential amino acids, fatty acids, vitamins and minerals which are lack in plant based food, but it is devoid of dietary fiber, which is very essential component for normal physiological/biochemical process. During meat products processing its functional values can be improved by supplementation of dietary fiber rich vegetative substances like cereal and pulse flour, vegetable and fruits pulp etc. by this process a significant proportion of required daily allowance of dietary fiber can be fulfilled for the frequent meat consumers. The consumption of meat products fortified with of dietary fiber can lead to the prevention of diseases like coronary heart disease, diabetes, irritable bowel disease, obesity etc. On the other hand the dietary fiber can effectively incorporated in the processed meat products as binders, extender and filler, they can significantly replace the unhealthy fat components from the products; increase acceptability by improving nutritional components, pH, water holding capacity, emulsion stability, shear press value, sensory characters etc. of finished products. Addition of dietary fiber in the meat products can increase the cooking yield therefore the economic gain as well.

6.1. Effect of fiber addition on physico-chemical properties of meat products

Functional property of fibers has a profound effect on physicochemical properties of the meat. Fiber addition in meat results in decreasing cooking loss, alteration in pH and an increase in emulsion stability. The higher emulsion stability resulting in a higher cooking yield of emulsion based meat products is important from technological as well as economical point of view. The change in pH on addition of dietary fiber source largely depends upon the pH of the fiber source added.

Grigelmo-Miguel *et al.*, (1999) used two different peach dietary fibre (DF) suspensions (17 and 29%) were used to obtain low-fat high-DF frankfurters (20% fat) which were compared to an all-meat control (25% fat). The viscosity of the meat batters increased with DF content. The

protein (11.5%) and collagen (1.4%) contents of frankfurters were not affected by DF addition, and the higher the DF content, the lower the pH (6.4 to 5.8) due to the fibre solution acidity. Alesson-Carbonell *et al.*, (2004) treated dry-cured sausages with two types of dehydrated lemon albedo (raw and cooked) at five concentrations (0–100 g kg⁻¹ in 25 g kg⁻¹ increments). The addition of albedo improved the nutritional properties as a result of fibre addition and beneficial effects due to the presence of active bio compounds. On the contrary, Fernandez- Lopez *et al.*, (2007) evaluated dry-cured sausages with added orange fibre. Addition of dried orange fibre at 10, 15 and 20 g/kg level in dry cured fermented sausage decreased pH during curing process. With increasing concentration of fibre, pH decreased progressively. Fruit by-products viz., kinnow rind powder (KRP), pomegranate rind powder (PRP) and pomegranate seed powder (PSP) in goat meat patties. It was concluded that extracts of above fruits by-product powders have potential to be used as natural antioxidants in meat products (Devatkal *et al.*, 2010). An increase in pH with the incorporation of dietary fiber has been reported by Rao and Reddy (2000) in chicken loaves added with Bengal and Black gram flour. Rye bran was incorporated at four different levels viz. 5, 10, 15 and 20 % and results revealed that the pH increased significantly ($p \leq 0.05$) at 10 % level as compared to control (Yilmaz 2004). Similar increase in pH value was again reported in meatballs incorporated with wheat bran at 5, 10, 15 and 20 % levels and the highest pH was obtained with addition of 20 % wheat bran (Yilmaz 2005). Talukdar and Sharma (2010) incorporated wheat bran and oat bran at 5, 10 and 15 % levels in chicken meat patties. They reported an increase in pH of emulsion as well as cooked product on incorporation of wheat bran. Carrageenan and oat fibre on the hydration/binding properties, colour and flavour characteristics of frankfurters. Addition of carrageenan or oat fibre reduced cook loss and increased both water holding capacity and emulsion stability (Hughes *et al.*, 1997) Cofrades *et al.*, (2000) added soy fiber (SF) on bologna sausages favored the formation of harder, chewier structures with improved fat and water binding properties. Chang & Carpenter, (1997) evaluated Chicken frankfurters fat content decreased by using various levels of oat bran and added water. Frankfurters with higher levels of oat bran had less expressible moisture and required higher shear stress to break. Pea fiber incorporation in Patties and ground beef patties improved tenderness and cooking yields and showed less change in thickness during cooking, but required longer cooking times (Anderson and Berry, 2000). Lin and Lin (2004) also found that addition of Bacterial cellulose (Nata.) in Chinese-style meatball increased the water holding

capacity of raw meatballs than control but pattern was reversed after cooking because cooking losses of Nata-containing products were higher than that of control. Vural *et al.*, (2004) and Javidipour *et al.*, (2005) utilized sugar beet fiber and reported a significant increase in water holding capacity and total dietary fiber content of frankfurters and Turkish- type salami, respectively. The emulsion pH, emulsion stability and cooking yield were increased on incorporation of rice bran at different levels in meat batters (Choi *et al.*, 2007). The addition of dietary fibers from pea and wheat improved the water binding capacity including cooking yield and decreased the shrinkage in beef burgers (Besbes *et al.*, 2008). Hazelnut pellicle addition affected some quality parameters of beef burgers. The cooking yield and reduction in diameter and thickness of beef burgers improved by the addition of hazelnut pellicle. Beef burgers formulated with hazelnut pellicle had lower L, a and b values than control samples ($P < 0.05$). There were differences among beef burger samples in respect to sensory properties, control samples and 1% and 2% pellicle added samples had high acceptability. The results indicate that, 1–2% hazelnut pellicle can be used as a suitable dietary fiber source in low-fat beef burger production (Turhan *et al.*, 2005). Morin *et al.*, (2004) examined Interactions between meat proteins and beta glucan gum which reduced-fat (12%, w/w) sausages formulated with b-glucan at 0.3% and 0.8% (w/w) levels. Cooking loss results indicated that b-glucan gum held more water in cooked sausages than control gum (carboxy methyl cellulose), due to its ability to form a tighter network within the protein matrix, as shown by scanning electron microscopy.

6.2. Functional properties of dietary fiber in meat products

Utilization and incorporation of dietary fiber in meat products are gaining importance day by day. The suitability of fiber incorporation in meat products is increasing because of the numerous functional properties like water retention, lubrication, ability to decrease cooking loss, texture modification and neutral flavor (Akoh, 1998). Dietary fibers isolated from various plant sources such as dehydrated fruits, vegetables and cereal fibers has been used in the food industry and has shown the promising results (Viuda-Martos *et al.*, 2010). However, the fruit and vegetable fiber has found to have better oil binding capacity which is of significant importance in emulsion based products (Rodriguez *et al.*, 2006). The hydration and oil binding properties of dietary fiber are related to their chemical structure, pH, ionic strength and particle size (Fleury & Lahaye, 1991) (Table 14). Both of these properties in turn, affect the possibility about the use of various fibers as ingredients in meat products. For example, dietary fiber with high oil holding capacity

allows the stabilization of fat in emulsion based products whereas, the dietary fibers with high water holding capacity can be used as a functional ingredient to avoid syneresis and to modify the viscosity and texture of some formulated foods (Grigelmo-Miguel & Martina-Belloso, 1999). Various fiber sources like oat, sugar beet, soy, pea, psyllium etc. have been tried in formulation of some meat products such as patties and sausages (Andres, 1986). Fiber is also being used as an extender, binder and fat replacer in manufacturing various meat products (Modi *et al.*, 2009).

6.3. Effect of dietary fiber addition on proximate composition of meat products

Fiber addition in meat products can result in a change in overall composition of the final products. This has led to the emergence of novel sources of fibers, being offering new opportunities in their use in the industries (Guillon & Champ, 2000). Chang & Carpenter, (1997) worked on the addition of hydrated oat bran in frankfurters and found that moisture content and carbohydrate level increased with a subsequent increasing level of wheat and oat bran. However, moisture and fat content were decreased with increasing levels of oat bran. Dawkins *et al.*, (1999) formulated chevon (goat) meat-based patties with oat bran (15–50% w/w) and evaluated for nutrient content and physicochemical properties. Moisture, fat, and protein decreased with increased oat bran. Mansour & Khalil, (1999) reported an increase in moisture, protein, ash and carbohydrate content in cooked and uncooked beef burgers with hydrated wheat fiber (1:1). They explained that the decrease in fat content was due to the fact that wheat fiber was used as a fat replacer. Yasarlar *et al.*, (2007) studied the effect of cereal brans (oat, maize, rye and wheat) in the production of meatballs. The effects of bran addition on chemical composition, weight losses, dietary fibre content, colour and sensory properties of Turkish type meatballs were studied. Control samples and 10 % corn bran added samples had the highest overall acceptability scores and 15 % of corn bran addition also led to acceptable products. Modi *et al.*, (2009) prepared meat kofta by incorporation of 8% oat flour and with different concentrations of carrageenan in formulation of low-fat and high fiber meat product. Inclusion of oat flour and carrageenan in the formulation resulted in higher moisture retention and the yield on cooking and frying. Low fat high fiber meat kofta can be prepared by using 8.0% oat flour and 0.5% carrageenan without much detrimental effect on its physicochemical and sensory attributes. Addition of low fat soy flour and/or mung bean powder as meat extenders in buffalo meat at a level of 10% reduced the moisture and fat content, whereas increased the fiber and protein contents in the cooked samples (Kenawi *et al.*, 2009). Huang *et al.*, 2011 studied effect of addition of wheat fiber, oat fiber, and

inulin to Chinese-style sausages at level of 3.5% and 7%. Results showed that the type and amount of dietary fiber introduced did not significantly influence the general composition, color, and total plate count of sausages. However, the addition of wheat fiber and oat fiber significantly hardened the texture of Chinese-style sausages. Yilmaz (2004) reported a decrease in moisture and fat content but an increase in protein and ash content with an increasing amount of rye bran addition in low fat meatballs. Huang et al. (2005) found that use of rice bran in kung-wan, an emulsified pork meatball decreased protein and fat contents of meatballs, and in contrast, carbohydrate content significantly increased with increasing amount of rice bran. Yilmaz (2005) determined a decrement in fat and moisture content but an increment in protein and ash percent with increasing level of wheat bran viz. 5, 10, 15 and 20 % in low fat meatball but Saricoban *et al.*, (2009) reported that addition of wheat bran decreased protein and increased fat per cent of cooked beef patties. Serdaroglu (2006) used three concentrations of oat flour viz 0, 2 and 4 % (v/w) in beef patties and reported that addition of oat flour resulted in a decrease in moisture content in raw patties but an increase in cooked patties. The addition of oat flour did not change the protein, fat and ash content of raw or cooked patties. Choi *et al.*, (2008) reported an increase in ash content with addition of rice bran fiber to emulsion type sausages and low fat meat emulsions, respectively. Bilek and Turhan(2009) added flax seed flour at 3, 6, 9, 12 and 15 % concentration in beef patties and observed that with an increasing level of flax seed flour, fat and ash content increased while moisture and protein content decreased. Choi *et al.*, (2010) recorded the moisture, protein, fat and ash content of uncooked meat batter formulations with varying grape seed oil and rice bran fiber levels. They found that protein, fat and ash content of treatment with 20 % pork back fat and 2 % rice bran fiber was higher than treatment with only 20 % pork back fat. However, the moisture content was lower than in former. Similarly, addition of the dietary fibers (wheat fiber, oat fiber and inulin) resulted in significantly lower moisture content than control in Chinese style sausages (Huang *et al.*, 2011). The experimental and control groups did not exhibit significant differences in crude fat and protein contents but the crude fiber content increased with added dietary fiber. Grinded sausages with wheat fiber and oat fiber levels at 7.5 and 10 % resulted in lower fat contents in comparison to control sausages while protein content did not differ significantly (Szczepaniak *et al.*, 2005).

6.4 Effect of dietary fiber on sensory properties of meat products

Sensory property of meat products is a complex trait which depends on aroma and flavour, colour, appearance, tenderness and juiciness. Out of all the above sensory parameters, flavor and texture are given more weightage by the consumer. According to Risvik (1994), tender and juicy meat is generally preferred by the consumers. Anderson and Berry, (2000) addition of pea cotyledon fiber in low fat (10 and 14 %) beef patties resulted in improved tenderness without any negative effect on juiciness or beef flavor intensity. Garcia *et al.*, (2006) studied Inulin effect on the textural and sensory properties of mortadella, a Spanish cooked meat product. Textural analysis indicated that powdered inulin increases hardness. It can be established that this product can be enriched with inulin to a maximum level of 7.5% and preferably as gel with a good sensory quality. (Yilmaz, 2005) incorporated wheat bran as a fat substitute in the production of meatballs with four different formulations including 5%, 10%, 15% and 20% wheat bran addition. Control samples were formulated with 10% fat addition. There was significant difference among the meatball samples in respect to sensory properties and control samples had higher acceptability than the other meatball samples. Eim *et al.*, (2008) formulated dry fermented sausage, known as sobrassada, containing different percentages of carrot dietary fibre from 3 to 12 %. Addition of carrot dietary fiber to sobrassada modified the organoleptic properties depending upon the concentration. All the sensory attributes were declined when the level of added dietary fiber was greater than 3 %. Lee et al., (2008) determined the effect of addition of kimchi powder on textural properties of the breakfast sausages. Treatment containing 2 % kimchi powder had a higher hardness, gumminess and chewiness as compared to control. Kenawi *et al.*, (2009) studied the effect of adding low fat soy flour and/or mung bean powder as meat extenders. The product containing 5 % of both low fat soy flour and mung bean powder had the highest values for colour, taste, odour, juiciness and overall acceptability. Addition of low fat soy flour and mung bean powder increased the juiciness of patties as compared to control. Verma *et al.*, (2009) incorporated various dietary fiber sources like pea hull flour, apple pulp, gram hull flour and bottle gourd in different combinations in low fat chicken nuggets. There were differences in different quality attributes among control and treated products but organoleptically latter were comparable to former. Yilmaz & Gegel, (2009) reported that sensory scores of veal meatballs with 10, 15 and 20 % added inulin were less acceptable than control due to hardness, low juiciness and low flavor intensity. Viuda-Martos *et al.*, (2010) also reported a decrease in juiciness and increase in hardness perception on sensory analysis of mortadellas added with

orange dietary fiber. Global appearance, saltiness, fatness and acid taste were not affected by orange dietary fiber.

6.4. Fiber and textural properties of meat products

The three important components of food acceptability are texture, appearance and flavour. Though there is no alternative of human perception for texture measurement but most common used for measurement is Instron Texture Analyzer. Lin and Lin, (2004) reported that addition of bacterial cellulose (Nata.) in Chinese style meatball resulted in detrimental effect on textural attributes. The values for hardness, cohesiveness, springiness, chewiness and shear force showed a decreasing pattern with an increasing level of Nata incorporation. Garcia *et al.*, (2006) reported an increase in hardness value of mortadella, a Spanish cooked meat product incorporated with inulin. Inulin in powdered form increased hardness at 2.5 % level while in gel it affected hardness at 7.5 %. Saricoban *et al.*, (2009) adopted a three-factor Box- Behnken design for studying the simultaneous effects of processing variables such as fat (10–30 %), wheat bran (5–15 %) and NaCl (0–2 %) on physico-chemical, textural and sensory properties of cooked beef patties. They found that addition of wheat bran increased hardness and gumminess but decreased springiness, resilience and cohesiveness without influencing adhesiveness of the cooked beef patties. Choi *et al.*, (2011) studied the addition of rice bran fiber on the textural properties of heat induced gel and found that hardness was significantly lower in gels with added rice bran fiber than the control samples. Similarly, springiness, cohesiveness, gumminess and chewiness were lower in all samples with added rice bran fiber relative to control. Wan Rosli *et al.*, (2011) studied the textural properties of chicken patties formulated with different levels of grey oyster mushroom at 0, 25 or 50% as fiber source and fat replacer. They found that hardness of chicken patties decreased proportionally with the increasing level of oyster mushroom. Also, the cohesiveness, gumminess and chewiness of oyster mushroom based patties had lower values than control while springiness was higher than control chicken patties. Kimchi powder addition on textural properties of the breakfast sausages were reported by Lee *et al.*, (2008). Treatment containing 2 % kimchi powder had a higher hardness, gumminess and chewiness as compared to control. Similar increases in above textural parameters have been reported for frankfurters and bologna due to addition of soy fiber, plasma protein and other types of fiber (Confrades *et al.*, 2000).

6.5. Quality characteristics of fiber rich meat products during storage

Maintaining stability and superior quality of a meat product during storage period is of utmost importance. Addition of various types of fiber source in meat products have been found to influence the storage quality in various ways. Prasad *et al.*, (2011) reported that oat flour had better inhibition of oxymyoglobin oxidation when added in chicken kofta as compared to control. The product was also found to be microbiologically safe and sensorily acceptable during the 15 days of storage. Modi *et al.*, (2003) has observed that the buffalo meat burger containing roasted flours registered lower TBA values which signifies lower lipid oxidation than control. The burgers were found to be organoleptically acceptable after storage for 4 months. Alvarez *et al.*, (2011) found that the antioxidant activity of rice bran added frankfurters was preserved till 14 days of storage showing an efficient protection against lipid oxidation. On the contrary, Choi *et al.*, (2010) found a higher lipid oxidation in rice bran supplemented frankfurters. During storage the change in pH of meat products is an interesting phenomenon. Modi *et al.*, (2009) had reported a decrease in pH of fried mutton kofta added with oat flour during storage period for 6 weeks. But an increased alkalinity resulting in higher pH was observed in rice bran fiber added pork salt soluble meat proteins in a model system (Choi *et al.*, 2011). Similar findings were observed by Verma *et al.*, (2009) in storage of chicken nuggets with high fiber ingredients.

7. Challenges and future potential of fiber rich meat products

The suitability of dietary fiber incorporation in meat products is increasing because of its numerous functional properties like water retention, emulsion stability, lubrication, texture modification and neutral flavor. Various fiber sources like oat, rice, sugar beet, soy, pea, psyllium etc. have been tried in formulation of some meat products such as patties and sausages for development of nutritionally balanced diet. Fiber is also being used as a fat replacer in manufacturing of various meat products. Other than the nutritional properties, dietary fiber is now used in meat products for technological up gradation like improvement in cooking yields, rheological properties, reducing formulation costs and enhancing the palatability and texture of meat products. The dietary fiber rich meat products are considered clinically better than traditional meat products. But the real challenge actually lies in effective development and marketing of these functional meat products. Even from the consumer perspective, the trust on the composition and desired outcome of fiber rich meat products on regular consumption has to be widely studied. The development of meat products enriched with fiber is indeed a novel area.

A lot of work is still left to unfold the real potential of those components which are scarcely used in diet or are now eliminated from diet due to change in food habits.

8. Conclusion

The incorporation of dietary fibers, either soluble or insoluble in the meat products is considered need of the time in view of their various health benefits. In the era of globalization and fast foods, consumption of dietary fibers can be beneficial as for as various nutritional and diet related disorders are concerned, particularly when the number of patients with such problems are increasing. Various sources of dietary fibers have been explored by different researchers, which are being attempted in the meat products. These sources markedly enhance the dietary fibers content in meat products and making them more functional as well as healthier. The meat products can be enriched with adequate amount of dietary fibers by wise selection of fibers sources and by method of incorporation. Thus it is expected that more acceptable novel meat products with promising health benefits will be available in future.

References

- AACC (2001) The definition of dietary fiber. AACC report. *Cereal Foods World* 46:112–126.
- Alesson-Carbonell, L., Fernandez-Lopez, J., Sendra, E., Sayas Barbera, E., Perez-Alvarez, J.A.2004. Quality characteristics of non-fermented dry cured sausage formulated with lemon albedo. *Journal of Science and Food Agriculture*, 84:2077–2084.
- Alvarez, D., Delles, R.M., Xiang, Y.L., Castillo, M., Payne, F.A., Laencina, J. 2011. Influence of canola olive oils, rice bran and walnut on functionality and emulsion stability of frankfurters. *Journal of Food Science and Technology*, 44:1435–1442.
- Anderson, E.T., Berry, B.W. 2000. Sensory, shear and cooking properties of low-fat beef patties made with inner pea fibre. *Journal of Food Science*, **65**(5):805–810.
- Andres, C. 1986. Multifunctional fiber provides nutrition, texture and increased functionality. *Food Process*, **47**(13):39–40.
- Aspinall, G.O. 1970. Polysaccharides. Pergamon Press, Oxford, pp 130–144.
- BeMiller, J.N. 2004. Dietary fiber intake, disease prevention, and health promotion: an overview with emphasis on evidence from epidemiology. In: Van-der Kamp JM, Asp NG, Miller,J., Schaafsma, G. (eds) Dietary fiber. Wageningen Academic Publishers, The Netherlands, pp 143–164.

- Best,D.1991. Whatever happened to fiber. *Prepared Foods*,160:54–56.
- Biesalski, H.K.2005. Meat as a component of a healthy diet – are there any risks or benefits if meat is avoided in the diet? *Meat Science*, 70:509–524.
- Brennan, C.S. 2005. Dietary fibre, glycaemic response, and diabetes. *Molecular Nutritional Food Research*, 49:560–570.
- Briggs, G.M., & Schweigert, B.S. 1990. An overview of meat in the diet. In A.M. Pearson, & T.R. Dutson, *Advances in Meat Research* 6,1-18. New York: Elsevier Applied Science.
- Brown,L., Rosner, B., Willett, W.W. & Sacks, F.M. 1999. Cholesterol lowering effects of dietary fiber: a meta-analysis. *American Journal of Clinical Nutrition*,69:30–42.
- Chang, H.C. & Carpenter, J.A. 1997. Optimizing quality of frankfurters containing oat bran and added water. *Journal of Food Science*, 62(1):194–197.
- Chawla R, Patil GR (2010) Soluble dietary fiber. *Comp Rev Food Sci F* 9:178–196.
- Cheeke, P.R. 2005. *Applied animal nutrition*. 3rd Edition. Lebanon, Indiana: Prentice Hall.
- Choi, Y.S., Choi, J.H., Han, D.J., Kim, H.Y., Lee, M.A., Kim, H.W., Jeong, J.Y. & Kim, C.J.2011. Effects of rice bran fiber on heat induced gel prepared with pork salt soluble meat proteins in model system. *Meat Science*, 88:59–66.
- Claus, J.R. & Hunt, M.C.1991. Low-fat, high added water bologna formulated with texture-modifying ingredients. *Journal of Food Science*, 56: 643–647
- Colmenero, F.J., Ayo, M.J. & Carballo, J. 2005. Physicochemical properties of low sodium frankfurter with added walnut: effect of transglutaminase combined with caseinate, KCl and dietary fiber as salt replacers. *Meat Science*, 69(4):781–788.
- Confrades, S., Guerra, M.A., Carballo, J., Ferna’ndez-Marti’n, F. & Jime’nez- Colmenero ,F. 2000. Plasma protein and soy fiber content effect on bologna sausage properties as influenced by fat level. *Journal of Food Science*, 65(2):281–287.
- Cummings, J.H.1993. The effect of dietary fiber on faecal weight and composition. In: Spiller GA (ed) *Handbook of dietary fibre in human nutrition*. CRC Press, Boca Raton, p 263.
- Dawkins, N.L., Phelps, O., Mcmillan, K.W. & Forrester, I.T. 1999. Composition and physicochemical properties of chevon meat patties containing oat bran. *Journal of Food Science*,64(4):597–600.

- 627 Devatkal, S.K., Narsaiah, K. & Borah, A. 2010. Anti-oxidant effects of extracts of
628 kinnow rind, pomegranate rind and seed powders in cooked goat meat patties. *Meat Science*,
629 85(1):155–159.
- 630 Dhingra, D., Michael, M., Rajput, H. & Patil, R.T. 2012. Dietary fibre in foods: a
631 review. *Journal of Food Science & Technology*, 49(3):255–266.
- 632 Dunaif, G., Schneeman, B.O. 1981. The effect of dietary fiber on human pancreatic
633 enzyme activity in vitro. *American Journal of Clinical Nutrition*, 34:1034– 1035.
- 634 Eastwood, M.A. 1992. The physiological effect of dietary fiber: an update. *Annual*
635 *Revision of Nutrition*,12:19–35.
- 636 Eim, V.S., Small, S., Rossello, C. & Femenia. A. 2008. Effect of addition of carrot
637 dietary fibre on the ripening process of a dry fermented sausage (Sobressada). *Meat*
638 *Science*,80:173–182.
- 639 Fahrenbach, M.J., Riccardi, B.A., Saunders, J.C., Lourie, I.N.& Heider, J.G. 1965.
640 Comparative effctcs of guar gum and pectin on human serum cholesterol levels. *Circulation*
641 31:11.
- 642 Garvin, J.E., Forman, D.T., Eiseman, W.R. & Phillips, C.R. 1965. Lowering of human
643 serum cholesterol by an oral hydrophilic colloid. *Proc Soc Exp Biol Med* 120:744–746.
- 644 Fernandez-Lopez, J., Sendra, E., Sayas-Barbera, E., Navarro, C. & Perez- Alvarez, J.A.
645 2008. Physico-chemical and microbiological profiles of “salchichon” (Spanish dry – fermented
646 sausage) enriched with orange fiber. *Meat Science*, 80:410–417.
- 647 Fernandez-Lopez, J., Viuda-Martos, M., Sendra, E., Sayas-Barbera, E., Navarro, C. &
648 Perez Alvarez, J.A. 2007. Orange fiber as potential functional ingredient for dry cured sausages.
649 *Europain Food Research & Technology*, 226:1–6.
- 650 Field, C.J., McBurney, M.I., Massimino S, Hayek MG, Sunvold GD (1999) The
651 fermentable fiber content of the diet alters the function and composition of canine gut associated
652 lymphoid tissue. *Veternairy Immunology and Immunopathology*, 72:325–341.
- 653 Fleury, N. & Lahaye, M. 1991. Chemical and physico-chemical characterization of fibres
654 from *Laminaria digitata* (Kombu breton): a physiological approach. *Journal of Science and*
655 *Food Agriculture*, 55:389–400.

- 656 Gallaher, D. D., Locket, P.L. & Gallaher, C.M. 1992.Bile acid metabolism in rats fed two
657 levels of corn levels and brans of oat, rye and barley and sugar beet fiber. *Journal of Nutrition*,
658 122:473–481.
- 659 Garcia, M.L., Caceres, E. & Selgas, M.D. 2006. Effect of inulin on the textural and
660 sensory properties of mortadella, a spanish cooked meat product. *International Journal of Food*
661 *Science and Technology*, 41:1207–1215.
- 662 Gibson, G.R. 2004. Fibre and effects on probiotics (the prebiotic concept). *Clinical*
663 *Nutritional Supplement*, 1:25–31.
- 664 Grasten, S., Liukonnen, K-H., Chrevatidis, A., Nezami, H., Poutanen, K. & Mykkanen,
665 H. 2003. Effects of wheat pentosan and inulin on the metabolic activity of fecal microbiota and
666 on bowel function in healthy humans. *Nutritional Research*, 23:1503–1514.
- 667 Grigelmo-Miguel, N., Abadias-Seros, M.I. & Martin-Belloso, O. 1999. Characterisation
668 of low-fat high-density fibre frankfurters. *Meat Science*, 52(3):247–256.
- 669 Guillon, F. & Champ, M. 2000. Structural and physical properties of dietary fibers and
670 consequences of processing on human physiology. *Food Research and International*,33:233–
671 245.
- 672 Harris, P.J & Ferguson, L.R. 1993. Dietary fibre: its composition and role in protection
673 against colorectal cancer. *Mutation of Research*, 290:97–110.
- 674 Haub, M.D., Hubach, K.L.& Al-Tamimi, E.K. 2010. Different types of resistant starch
675 elicit difference glucose responses in humans. *Journal of Nutritional*, Metab Article ID 230501.
- 676 Hipsley, E.H. 1953. Dietary fiber and pregnancy toxemia. *Bratian Medical Journal*,
677 2:420–442.
- 678 Huang ,S.C., Shiau, C.Y., Liu, T.E., Chu, C.L. & Hwang, D.F.2005. Effects of rice bran
679 on sensory and physico chemical properties of emulsified pork meatballs. *Meat Science*, 70:613–
680 619.
- 681 Huang, S.C., Tsai, Y.F. & Chen, C.M. 2011. Effects of wheat fiber, oat fiber and inulin
682 on sensory and physico-chemical properties of Chinese-style sausages. *Asian-Australlian*
683 *Journal of Animal Science*, 24(6):875–880.
- 684 Hughes, E., Calfrades, S. & Troy, D.J. 1997. Effect of fat level, oat fiber and carrageenan
685 on frankfurters with 5, 12 or 30 % fat. *Meat Science*, 45(3):273–281.

- 686 Jenkins, D.J.A., Leeds, A.R., Gassull, M.A., Cochet, B. & Alberti, K.G.M.M. 1977.
687 Decrease in postprandial insulin and glucose concentrations by guar and pectin. *Ann Intern Med*
688 86:20–23.
- 689 Jenkins, D.J.A., Wolever, T.M.S., Leeds, A.R., Gassull, M.A., Haisman, P., Dilawari, J.,
690 Goff, D.V., Metz, G.L.& Alberti, K.G.M.M.1978. Dietary fibres, fibre analogues, and glucose
691 tolerance: importance of viscosity. *Bratain Medical Journal*, 1:1392–1394.
- 692 Johnson, I.T & Southgate, D.A.T. 1994. Dietary fibre and related substance. In: Food
693 Safety Series. Edelman J, Miller S (eds), Chapman & Hall, London, p 39–65.
- 694 Kay, R.M. 1982. Dietary fibre. *Journal of Lipid Research*, 23:221–242.
- 695 Kenawi, M.A., Abdelsalam, S.A. & El-Sherif, S.A.2009. The effect of mung bean
696 powder, and/or low fat soy flour as meat extender on the chemical, physical and sensory quality
697 of buffalo meat product. *Biotechnology and Animal Husbandry*, 25(5–6):327–337.
- 698 Kendall, C.W., Esfahani, A. & Jenkins, D.J.A. 2009. The link between dietary fiber and
699 human health. *Food Hydrocolloids*, 24(1):42–48.
- 700 King, J.C. & Turnlund, J.R. 1989. Human zinc requirements. Dietary pattern and zinc
701 supply. In C.F. Mills, *Zinc in Human Biology* (pp. 351-363). Laufen: Springer Verlag.
- 702 Kritchevsky, D. 2000. Dietary fibre in health and disease. In: Proc1st International
703 Confession Dietary fibre, McCleary, B.V., Prosky, L (eds), Dublin,Ireland, 14–17 May,
704 Blackwell Science, Oxford, UK, p 38.
- 705 Latunde-Dada, G.O. & Neale, R.J. 1986. Review: Availability of iron from foods.
706 *Journal of Food Technology*, 21: 255-268.
- 707 Lawaetz ,O., Blackburn, A.M., Bloom, S.R., Aritas, Y. & Ralphs, D.N.L. 1983. Effect of
708 pectin on gastric emptying and gut hormone release in the dumping syndrome. *Scandish Journal*
709 *of Gastroenterology*, 18:327–336.
- 710 Lin, K.W. & Lin, H.Y. 2004. Quality characteristics of Chinese-style meatball containing
711 bacterial cellulose (Nata.). *Journal of Food Science*, 69(3):107–111.
- 712 Mälkki, Y. 2001. Oat fiber. Production, composition, physicochemical properties,
713 physiological effects, safety, and food applications. In: Cho SS, Dreher ML (eds) Handbook of
714 dietary fiber. Marcel Dekker, Inc, New York, pp 497–517.
- 715 Mansour, E.H & Khalil, A.H. 1999.Characteristics of low-fat beefburgers as influenced
716 by various types of wheat fibers. *Journal of Science and Food Agriculture*, 79:493–498

- 717 McCleary, B.V. 2008. Measurement of dietary fibre components: the importance of
718 enzyme purity, activity and specificity. In: McCleary, B.V.& Prosky, L. (eds) Advanced dietary
719 fibre technology. Blackwell Science Ltd, Oxford, pp 89–105.
- 720 McDowell, L.R. 2000. Vitamins in Animal and Human Nutrition, 2nd Edition. Iowa:
721 Iowa State University Press.
- 722 Mehta, K. & Kaur, A. 1992. Reviews: dietary fiber. *International Journal of Diabetes*
723 *Development Ctries*, 12:12–18.
- 724 Modi, V.K., Mahendrakar, N.S., Narsimha Rao, D. & Sachindra, N.M. 2003. Quality of
725 buffalo meat burger containing legume flour as binders. *Meat Science*, 66:143–149.
- 726 Modi, V.K., Yashoda, K.P., Bhaska, N. & Mahendrakar, N.S. 2009. Effect of
727 carrageenan and oat flour on storage characteristics of fried mutton kofta. *Journal of Food*
728 *Process & Preservation*, 33(6):763–776.
- 729 Morin, L.A., Temelli. F. & McMullen, L. 2004. Interaction between meat proteins and
730 barley Hordeum spp. β -glucan within a reduced-fat breakfast sausage system. *Meat Science*,
731 68:419–430.
- 732 Mun, S., Decker, E.A., Park, Y., Weiss, J & McClements, D.J. 2006. Influence of
733 interfacial composition on in vitro digestibility of emulsified lipids: potential mechanism for
734 chitosan's ability to inhibit fat digestion. *Food Biophysics*, 1(1):21–29.
- 735 Nayak, S.K., Pattnaik, P. & Mohanty, A.K. 2000. Dietary fiber: a low-calorie dairy
736 adjunct. *Indian Food Industry*, 19(4):268–274.
- 737 Pellett, P.L., & Young, V.R. 1990. Role of meat as a source of protein and essential
738 amino acids in human protein nutrition. In A.M. Pearson, & T.R. Dutson, *Advances in meat*
739 *research* 6, 329-370. New York: Elsevier Applied Science.
- 740 Potter, J.D. 1999. Colorectal cancer: molecules and populations. *Journal of Natural*
741 *Cancer Institute*, 91:916–932.
- 742 Prasad, B., Rashmi, M.D., Yashoda, K.P. & Modi, V.K. 2011. Effect of casein and oat
743 flour on physicochemical and oxidative processes of cooked chicken kofta. *Journal of Food*
744 *Process & Preservation*, 35(3):359–368.
- 745 Puupponen-Pimia, R., Aura, A.M., Oksman-Caldentey, K.M., Myllarinen, P., Saarela,
746 M., Mattila-Sandholm, T. & Poutanen. K. 2002. Development of functional ingredients for gut
747 health. *Trends in Food Science & Technology*, 13:3–11.

- 748 Raymann, M.P. 2000. The importance of selenium to human health. *Lancet*, 356, 233-
749 241.
- 750 Risvik, E. 1994. Sensory properties and preferences. *Meat Science*, 36:677.
- 751 Anderson, E.T. & Berry, B.W. 2000. Sensory, shear and cooking properties of low-fat
752 beef patties made with inner pea fibre. *Journal Food Science*, 65(5):805–810.
- 753 Rodriguez, R., Jimenez, A., Fernández-Bolaños, J., Guillen, R. & Heredia, A. 2006.
754 Dietary fibre from vegetable products as source of functional ingredients. *Trends Food Science*
755 *Technology*, 17(1):3–15.
- 756 Rumney, C. & Rowland, I.R. 1995. Nondigestible oligosaccharides potential anti-cancer
757 agents? *BNF Nutritional Bulletin*, 20:194–203.
- 758 Sahlin, A. & House, J.D. 2006. Enhancing the vitamin content of meat and eggs:
759 Implications for the human diet. *Canadian Journal of Animal Science*, 86: 37-48.
- 760 Sanchez-Zapata, E., Munoz, C.M., Fuentes, E., Fernandez-Lopez, J., Sendra, E., Sayas,
761 E. & Navarro, C. 2010. Effect of tiger nut fibre on quality characteristics of pork burger. *Meat*
762 *Science*, 85:70–76.
- 763 Saricoban, C., Yilmaz, M.T. & Karakaya, M. 2009. Response surface methodology study
764 on the optimization of effects of fat, wheat bran and salt on chemical, textural and sensory
765 properties of patties. *Meat Science*, 83:610–619.
- 766 Schubert, W.J. 1956. Lignin biochemistry. Academic, New York, pp 2–6.
- 767 Seuss, I.K., Honikel, K.O., & Scholz, W. 1988. Zum Nährstoffgehalt von Rind- und
768 Schweinefleisch. I. Rohes Fleisch. *Fleischwirtschaft*: 68,839-841, 880.
- 769 Sharma, A., Yadav, B.S. & Ritika, B. 2008. Resistant starch: physiological roles and food
770 applications. *Food Review International*, 24:193–234.
- 771 Talukdar, S. & Sharma, D.P. 2010. Development of dietary fiber rich chicken meat patties
772 using wheat and oat bran. *Journal and Food Science & Technology*, 47(2):224–229.
- 773 Tapsell, L.C. 2004. Diet and metabolic syndrome: where does resistant starch fit in?
774 *Journal Association Analas Chemistry International*, 87(3):756–760.
- 775 Trowell, H. 1976. Definition of dietary fiber and hypotheses that it is a protective factor
776 in certain diseases. *American Journal of Clinical Nutritional*, 29(4):417– 427.
- 777 Turhan, S., Sagir, I. & Ustun, N.S. 2005. Utilization of hazelnut pellicle in low-fat beef
778 burgers. *Meat Science*, 71:312–316.

- 779 Van Soest, P.J. 1976. Fiber composition of some food stuffs. *American Journal of*
780 *Clinical Nutrition*, 31:5282–5284
- 781 Verma, A.K., Sharma, B.D. & Banerjee, R. 2009. Quality characteristics and storage
782 stability of low fat functional chicken nuggets with salt substitute blend and high fibre
783 ingredients. *Fleis- chwirtschaft International*, 24(6):52–57
- 784 Viuda-Martos, M., Ruiz-Navajas, Y., Fernandez-Lopez, J.& Perez-Alvarez, J.A. 2010.
785 Effect of orange dietary fibre, oregano oil and packaging conditions on shelf-life of bologna
786 sausages. *Food Control*, 21:436–443.
- 787 Welsh ,S., Shaw, A. & Davis, C. 1994. Achieving dietary recommendation: wholegrain
788 foods in the food guide pyramind. *Critical review of Food Science & Nutrition*, 34:441–451.
- 789 Wursch, P. & Pi-Sunyer, X. 1997. The role of viscous soluble fiber in metabolic control
790 of diabetes. *Diabetic Care*, 20:1774–1780.
- 791 Yilmaz, I. 2005. Physicochemical and sensory characteristics of low fat meatballs with
792 added wheat bran. *Journal of Food Engineering*, 69:369–373.
- 793 Yilmaz, I. & Gegel, U. 2009. Effect of inulin addition on physico chemical and sensory
794 characteristics of meatballs. *Journal of Food Science & Technology*, 46:473–476.
- 795 Wang, J., Rosella, C. M and Barbera, C. B. 2002. Effect of the addition of different fibres
796 on wheat dough performance and bread quality. *Food Chemistry* **79**: 2.21-226.
- 797 Elleuch, M., Bedigian, D., Besbes, S and Blecker, C. 2011. Dietary fibre and fibre-rich
798 by-products of food processing: Characterisation, technological functionality and commercial
799 applications: A review. *Food Chemistry* **124**: 411-421
- 800 Thebaudin, J.Y., Lefebvre, A.C., Harrington, M. & Bourgeois, C.M. 1997. Dietary fibres:
801 Nutritional and technological interest. *Trends in Food Science & Technology* **8**: 41-48.
- 802 Serdaroglu, M 2006. The characterisitcs of beef patties containing different levels of fat and oat
803 flour. *Int J Food Sci Technol* 41:147–153.
- 804 Choi YS, Jeong JY, Choi JH, Han DJ, Kim HY, Lee MA 2008) Effects of dietary fiber from rice
805 bran on the quality characteristics of emulsion type sausages. *J Korean Soc Food Sci*
806 *Anim Res* 28(1):14–20.
- 807 Bilek AE, Turhan S (2009) Enhancement of the nutritional status of beef patties by adding flax
808 seed flour. *Meat Sci* 82:472–477.

- 809 Choi YS, Choi JH, Han DJ, Kim HY, Lee MA, Kim HW, Lee JW, Chung HJ, Kim CJ (2010)
810 Optimization of replacing pork back fat with grape seed oil and rice bran fiber for
811 reduced-fat meat emulsion systems. *Meat Sci* 84(1):212–218.
- 812 Szczepaniak B, Piotrowska E, Dolata W, Zawirska-Wojtasiak R (2005) Effect of partial fat
813 substitution with dietary fiber on sensory properties of finely comminuted sausages part I.
814 wheat and oat fiber. *Pol J Food Nutr Sci* 14/55(3):309–314.
- 815 Guillon F, Champ M (2000) Structural and physical properties of dietary fibers and
816 consequences of processing on human physiology. *Food Res Int* 33:233–245.
- 817 Yasarlar EE, Daglioglu O, Yilmaz I (2007) Effect of cereal bran addition on chemical
818 composition, cooking characteristics and sensory properties of Turkish meatballs. *Asian J*
819 *Chem* 19(3):2353–2361.
- 820 Yilmaz I (2004) Effect of rye bran addition on fatty acid composition and quality characteristics
821 of low fat meatballs. *Meat Sci* 67:245– 249
- 822 Grigelmo-Miguel N, Abadias-Seros MI, Martin-Belloso O (1999). Characterisation of low-fat
823 high-density fibre frankfurters. *Meat Sci* 52(3):247–256.
- 824 Devatkal SK, Narsaiah K, Borah A (2010) Anti-oxidant effects of extracts of kinnow rind,
825 pomegranate rind and seed powders in cooked goat meat patties. *Meat Sci* 85(1):155–159
- 826 Rao BJ, Reddy KP (2000) Influence of binders and refrigerated storage on quality of chicken
827 meat loaves. *Indian J Poult Sci* 35(3):302–305.
- 828 Vural H, Javidipour I, Ozbas Ozen O (2004) Effects of interesterified vegetable oils and
829 sugarbeet fiber on the quality of frankfurters. *Meat Sci* 67:65–72.
- 830 Javidipour I, Vural H, Ozbas OO, Tekin A (2005) Effect of interestified vegetable oils and sugar
831 beet fibre on the quality of Turkish-type salami. *Int J Food Sci Technol* 40(2):177–185.
- 832 Choi YS, Jeong JY, Choi JH, Han DJ, Kim HY, Lee MA et al (2007). Quality characteristics of
833 meat batters containing dietary fiber extracted from rice bran. *J Korean Soc Food Sci*
834 *Anim Res* 27(3):228–234.
- 835 Besbes S, Attia H, Deroanne C, Makni S, Blecker C (2008) Partial replacement of meat by pea
836 fiber: effect on the chemical composition, cooking characteristics and sensory properties
837 of beef burgers. *J Food Qual* 31:480–489.

- 838 Morin LA, Temelli F, McMilen L (2004) Interaction between meat proteins and barley
839 Hordeum spp. β -glucan within a reduced-fat breakfast sausage system. Meat Sci 68:419–
840 430.
- 841 Akoh CC (1998) Fat replacers. Food Technol 52(3):47–53
- 842 Rodriguez R, Jimenez A, Fernández-Bolaños J, Guillen R, Heredia A (2006) Dietary fibre from
843 vegetable products as source of functional ingredients. Trends Food Sci Technol 17(1):3–
844 15
- 845 Lee MA, Han DJ, Jeong JY, Choi JH, Choi YS, Ki HY, Paik HD, Kim CJ (2008) Effect of
846 kimchi powder level and drying methods on quality characteristics of breakfast sausage.
847 Meat Sci 80:708–714
- 848 Alvarez D, Delles RM, Xiang YL, Castillo M, Payne FA, Laencina J (2011) Influence of canola
849 olive oils, rice bran and walnut on functionality and emulsion stability of frankfurters. J
850 Food Sci Technol 44:1435–1442
- 851 Choi YS, Choi JH, Han DJ, Kim HY, Lee MA, Kim HW, Lee JW, Chung HJ, Kim CJ (2010)
852 Optimization of replacing pork back fat with grape seed oil and rice bran fiber for
853 reduced-fat meat emulsion systems. Meat Sci 84(1):212–218.
- 854 Fergus C (2004) Functional foods: opportunities and challenges. Food Technol 58(12):35–40.
- 855 Decker EA, Park Y (2010) Healthier meat products as functional foods. Meat Sci 86(1):49–55.
- 856 Chan W (2004) Macronutrients in meat. In: Jensen WK, Devine C, Dikeman M (eds)
857 Encyclopedia of meat sciences. Elsevier Academic Press, Oxford, pp 614–618.
- 858 Saiga A, Okumura T, Makihara T, Katsuta S, Shimizu T, Yamada R (2003) Angiotensin I
859 converting enzymes inhibitory peptides in a hydrolyzed chicken breast muscle extract. J
860 Agric Food Chem 51:174–1745
- 861 Vercruysse L, Van Camp J, Smagghe GJ (2005) ACE inhibitory peptides derived from
862 enzymatic hydrolysates of animal muscle protein: a review. J Agric Food Chem 53:8106–
863 8115.
- 864 Bhat ZF, Bhat H (2011) Functional meat products: a review. Int J Meat Sci 1(1):1–14
- 865 Roberfroid MB (2002) Global view on functional foods: European perspectives. Br J Nutr
866 88:5133–5138.
- 867 WHO/FAO (2003) Diet, nutrition and prevention of chronic diseases. WHO Technical report
868 series 916, Geneva, Switzerland.

869 Claus JR, Hunt MC (1991) Low fat, high added water bologna formulated with texture-
870 modifying ingredients. J Food Sci 56:643–647.

871

872