J Food Sci Technol (May–June 2010) 47(3):247–257
DOI: 10.1007/s13197-010-0039-8

REVIEW

Dietary fibre as functional ingredient in meat products: a novel approach for healthy living – a review

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Revised: 12 December 2009 / Accepted: 19 December 2009

Abstract There is a rapid change in our overall lifestyle due to impact of globalization. Every day hasty life has forced consumers to be dependent upon fast foods, which contain meagre amount of dietary fibre. Non-starch polysaccharides and resistant oligosaccharides, lignin, substances associated with NSP and lignin complex in plants, other analogous carbohydrates, such as resistant starch and dextrins, and synthesized carbohydrate compounds, like polydextrose are categorized as dietary fibre. They are mostly concentrated in cereals, pulses, fruits and vegetables. It has been proclaimed that daily dietary fibre intake helps in prevention of many nutritional disorders like gut related problems, cardiovascular diseases, type 2 diabetes, certain types of cancer and obesity. Meat is generally lacking this potential ingredient, which could be incorporated while products processing to make them more healthful. Various fibre rich sources have been attempted in different products attributed to their technological and health benefits and many are in the queue to be used in a variety of meat products. Selection of appropriate fibre rich ingredients and their proper incorporation can improve health image of meat products.

Keywords Meat products · Dietary fibre · Health

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Introduction

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, Kaefersteins and Clugston 1995, Beecher 1999). Various reports have revealed that intake of fibre reduces the risk of such diseases (NCI 1984, Eastwood 1992, 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-Pimïa 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 (Desmond et al. 1998a, Mansour and Khalil 1999) and meat emulsions (Claus and Hunt 1991, Chang and Carpenter 1997). In the present article, various sources of dietary fibres, their health benefits, application in meat products and effects on quality attributes have been reviewed.

Dietary fibre

The rediscovery of foods for health has been described as the functional foods revolution (Heasman and Mellentin 2001). Dietary fibre is among the food ingredients, now called nutraceuticals, which are shown to have the potential, if consumed in adequate amounts, to improve human health (IOM 2005). Because the term 'dietary fibre' encompasses a wide range of complex materials, it is difficult to define. Dietary fibre has a long history, its term originating with Hipsley (1953), and its definition has seen several revisions. One widely accepted definition from the American Association of Cereal Chemists states: "Dietary fibre is the remnants of the edible parts of plants or analogous carbohydrates that are resistant to digestion and absorption in the human small intestine with complete or partial fermentation in the large intestine……..Dietary fibres promote beneficial physiological effects including laxation, and/or blood cholesterol attenuation, and/or blood glucose attenuation" (AACC 2001). These definitions typically include the fibre components - non-starch polysaccharides (NSP) and resistant oligosaccharides, lignin, substances associated with NSP and lignin complex in plants, and other analogous carbohydrates, such as resistant starch and dextrins, and synthesized carbohydrate compounds, like polydextrose. Dietary fibre constituents are listed in Table 1.

Sources of dietary fibre

Dietary fibre is traditionally divided into 2 major groups: soluble and insoluble fibre. The soluble fibres are generally present at high levels in fruits, oats, beans and vegetables (Anderson et al. 1994). Whole grains are a major food source for insoluble fibres (Welsh et al. 1994, Slavin et al. 1997). Basically, the soluble or easily digestible fibres including pectins, gums, starches and other storage polysaccharides produce viscous solutions that delay gastric emptying and absorption from the small intestine and tend to lower blood cholesterol level. Such substances are greatly accessible to bacterial enzymes and are very rapidly fermented in the proximal colon and, hence, tend to have less impact on colonic transit. Insoluble fibres such as cellulose and lignins, by contrast, have much less effect on the viscosity of gut contents, tend to accelerate rather than delay small bowel transit and have more marked laxative effect than soluble fibre.

Dietary fibre and health benefits

Maintenance of gut health: Fibre increases stool weight and promotes normal laxation (Cummings 1993). The increase

Table 1 Dietary fibre constituents

Fibre constituent	Principal groupings	Fibre components/sources
Non-starch polysaccharides and oligosaccharides	Celluose	Cellulose-plants (vegetables, sugar beet, various brans)
	Hemicellulose	Arabinogalactans, β-glucans, arabinoxylans, glucuronoxylans, xyloglucans, galactomannans, pectic substances
	Polyfructoses	Inulin, oligofructans
	Gums and mucilages	Seed extracts (galactomannans –guar and locust bean gum), tree exudates (gum acacia, gum karaya, gum tragacanth), algal polysaccharides (alginates, agar, carrageenan), psyllium
Carbohydrate analogues	Pectins	Fruits, vegetables, legumes, potato, sugar beets
	Resistant starches and maltodextrins	Various plants such as maize, pea, potato
	Chemical synthesis	Polydextrose, lactulose, cellulose derviatives
	Enzymatic synthesis	Neosugar or short chain fructooligosaccharides, transgalactooligosaccharides, levan, xanthan gum, oligofructose, xylooligosaccharide, guar hydrolyzate, curdlan
Lignin	Lignin	Woody plants
Substances associated with nonstarch polysaccharides	Waxes,cutin Suberin	Plant fibres
Animal origin fibres	Chitin, chitosan, collagen, chondroitin	Fungi, yeasts, invertebrates

(Source: Tungland and Meyer 2002)

in stool weight is caused by the presence of fibre, by the water that the fibre holds and by partial fermentation of fibre that increases the amount of bacteria in stool (Kurasawa et al. 2000). The fermentation of dietary fibre in the colon has a number of desirable attributes. The main product of polysaccharide fermentation in the colon is bacterial biomass, which not only increases stool bulk (Bosaeus 2004) but gives rise to increased numbers or metabolic activity of main saccharolytic bacterial species. Increased stool bulk reduces colonic transit time which is beneficial not only for the relief and prevention of constipation, but in reducing the impact of detrimental microflora associated characteristics such as toxic nitrogenous compounds, hydrogen sulphide, and production of carcinogenic or genotoxic compounds (Gibson 2004).

Bacterial fermentation also results in lowering of colonic pH, which impedes the growth of certain pathogenic bacteria while encouraging the growth of bifidobacteria and lactic acid microflora. A low colonic pH may also aid in the excretion of carcinogens, which bind to dietary fibre in the colon (Rowland 1995). The short chain fatty acids, from fibre fermentation, particularly butyrate, play a key role in the health of colon. They influence both stimulation of cell division and regulation of apoptosis (Wasan and Goodlad 1996). Fig. 1 depicts possible effects of dietary fibre in large intestine.

Prevention of carcinogenesis: The role of dietary fibre in preventing colorectal cancer (CRC) continues to be a topic of heated debate. Animal and case-control studies strongly suggest that dietary fibre reduces the risk of CRC but human studies have shown mixed results. Some researchers have proposed that dietary fibres may impart anticarcinogenic and antitumorigenic effects by:

- Reducing the production of carcinogenic substances by decreasing the number of pathogenic bacteria in the colon (Rumney and Rowland 1995, Robertson et al. 1991).
- Lowering the colonic pH to affect pH-dependent enzymatic reactions as for example, formation of secondary bile acid (Rowland 1995, Buddington et al. 1996, Rowland et al. 1998).
- Increasing faecal bulk and thereby diluting its contents, which ultimately decrease effective interactions between the intestinal mucosa and any carcinogens that are present in the faeces; reducing intestinal transit times, allowing less opportunity for faecal mutagens to interact with the intestinal epithelium (Harris and Ferguson 1993).
- Exerting inhibitory effect on initiation and promotion stages in colon cancer formation in which short chain fatty acids, particularly butyric acid, may play a key role (Hague et al. 1993, Pierre et al. 1997, Reddy et al. 1997, Verghese et al. 1998).

A possible mechanism for the protective effect of fibres against breast cancer is that high fibre intakes result in increased faecal losses of oestrogens, which are associated with increased risk of breast cancer (Willett et al. 1992).

Effect on cardiovascular system: Well fermented fibre types that produce relatively high viscosity can lower the blood cholesterol (Ripsin et al. 1992), and epidemiological evidence supports the relationship between higher dietary fibre intake and reducing the risk of cardiovascular disease (Rimm et al. 1996, Wolk et al. 1999). Some workers have reported that the hypocholesterolemic effects of dietary

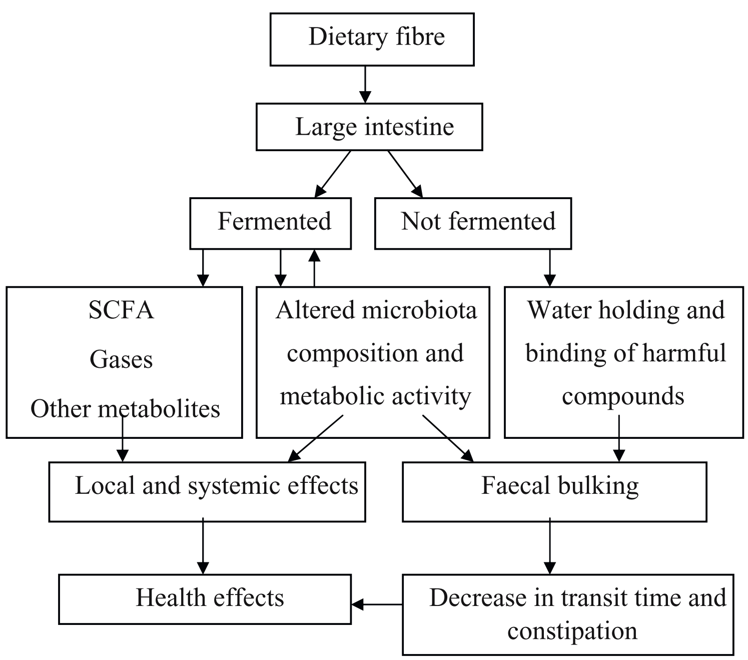

Fig. 1 Possible effects of dietary fibre in large intestine

fibre are due to increased excretion of bile acids and cholesterol (Bosaeus et al. 1986, Arjmandi et al. 1997). In addition, dietary fibre may delay the absorption of macronutrients including fat and carbohydrates. Delayed carbohydrate absorption could lead to increased insulin sensitivity (Hallfrisch et al. 1995) and decreased triacylglycerol concentrations (Rivellese et al. 1980) both considered as risk factors for coronary heart diseases. It has also been suggested that hypocholesterolemic effect of dietary fibres might also be mediated by the short chain fatty acids from fibre fermentation. Propionate is reported to inhibit fatty acid metabolism, which plays a key role in the synthesis of cholesterol (Nishina and Freeland 1990, Wright et al. 1990, Demignè et al. 1995).

Prevention of diabetes: Fibre intake especially from cereal origin, has consistently been shown to be inversely associated with type 2 diabetes risk (Jenkins et al. 1995, Chandalia et al. 2000). The protective effect may result from the ability of fibre to lower post-prandial glucose peak, which leads to decreased insulin demand and protects the pancreas from exhaustion. Fibre is known to slow down the digestion and absorption of carbohydrates, but this applies mostly to soluble fibre (Jenkins et al. 1978); however, specifically insoluble (cereal) fibre has in several studies been associated with decreased diabetes risk (Salmeron et al. 1997a,b, Meyer et al. 2000, Stevens et al. 2002, Montonen et al. 2003, Schulze et al. 2004). A possible mediator of the effect is the enhanced secretion of gut-hormones (glucoincretins) glucagon-like peptide-1 and gastric inhibitory peptide. They are intestinal peptides secreted in response to glucose, lipid, or non-digestible carbohydrate ingestion, and are responsible for the rapid insulin response to a meal (Burcelin 2005).

Dietary fibre and mineral bioavailability: Some studies have shown detrimental effect of wheat and corn fibres on iron and zinc absorption in animals and humans (Mason et al. 1990, Van Dokkum 1992). However, many studies revealed that dietary fibres do not inhibit iron or zinc absorption. These discrepancies may be because fibres often occur together with phytate, an inhibitor of iron and zinc absorption in humans and rats (Torre et al. 1991). The removal of phytate improved the bioavailability of Fe, Zn and Ca (Wisker et al. 1991), and phytate can be removed during processing of fibre ingredients. However, certain highly fermentable fibres have resulted in improved metabolic absorption of certain minerals, such as Ca, Mg, and Fe, even when phytic acid is present at lower concentrations (Schulz et al. 1993, Delzenne et al. 1995, Morais et al. 1996, Lopez et al. 1998). These compounds include pectin, gums, resistant starches, cellulose, oligosaccharides like soy and fructooligosaccharides, inulin, lactulose, and related sugars.

Satiety and obesity: Fibrous foods are slower to eat and result in greater and longer-lasting satiety (Stevens et al. 1987). Overall, high fibre diets especially those with fibre from cereals, fruits and vegetables and whole grains have been helpful in keeping the energy density of the diet low. Fibre and whole grains may provide several mechanisms, which may help in the maintenance or reduction of body weight. These include: (1) the promotion of satiation and lower caloric intake through more food volume, more chewing and more feelings of fullness (Jimenez-Cruz et al. 2006), (2) a decrease in absorption of macronutrients (Behall 1997), (3) a slowing of the rate of starch digestion (Brennan 2005), (4) an alteration of secretion of gut and other hormones such as adiponectin or insulin (Qi et al. 2006), (5) improved insulin sensitivity (Weickert et al. 2006) and (6) improved pancreatic functionality (Liese et al. 2005).

Application to meat products

Of late there is an increasing trend of fibre addition in meat products for technological reasons and benefits to human health (Vendrell-Pascuas et al. 2000). Fibre is suitable in meat products and has previously been used in meat emulsion products (Cofrades et al. 1995, Grigelmo-Miguel and Martin-Belloso 1999) because it retains water, decreases cooking losses and has a neutral flavour. Inclusion of dietary fibre in the meat matrix contributes to maintain its juiciness, which implies that the volatile compounds responsible for the flavour of product are more slowly released (Chevance et al. 2000). Several dietary fibres have been used as potential fat substitutes (Mansour and Khalil 1999).

At present, dietary guidelines recommend an increase in the consumption of whole grain cereal products due to their role in reducing the risk of degenerative chronic diseases. Several epidemiological studies have shown that consumption of whole grain cereals is associated with reduced incidences of diabetes (Liu et al. 2000, Pereira et al. 2002), cardiovascular diseases (Jacobs et al. 1998a) and certain cancers (Jacobs et al. 1998b). In general, cereal products are recognized sources of dietary fibre and many bioactive components such as lignans, phenolic acids, phytosterols, minerals, tocopherols and tocotrienols. These substances are mainly concentrated in the germ and outer layers of kernel (Nilsson et al. 1997, Glitsø and Bach Knudsen 1999).

In recent years legumes have also been investigated regarding their potential use in developing functional foods. Legumes provide energy, dietary fibre, proteins, minerals and vitamins required for human health. Legumes are considered as poor man's meat. They are generally good sources of slow release carbohydrates and are rich in proteins. Inclusion of legumes in the daily diet has many physiological effects in controlling and preventing various metabolic diseases such as mellitus, coronary heart disease and colon cancer (Tharanathan and Mahadevamma 2003).

Oat products have achieved a very positive consumer image because of the health benefits associated with their consumption. An inverse dose–response relationship between dietary oat fibre and serum cholesterol concentration has been reported, giving oat fibre a highly positive consumer perception (Shinnick et al. 1990). Oat bran or oat fibre appears to be a suitable fat replacement in ground beef and pork sausage products due to its ability to retain water and emulate particle definition in ground meat in terms of both colour and texture (Keeton 1994). Advantages of oat bran include its mouthfullness, which imitates fat, the lack of cereal flavour and the way it retains the natural flavourings of meat (Pszczola 1999). It also reduces fat absorption, slows carbohydrate absorption and aids satiety (Sloan 2003). Oat bran was used as a fat substitute in meatballs and it has been reported that meatballs containing oat bran had lower concentrations of total fat, and trans fatty acids than control samples (Yilmaz and Daglioglu 2003). Meatballs made with 20% oat bran had highest protein, ash contents, lightness, yellowness and lowest moisture as well as redness. There was no significant difference among the meatballs with sensory properties and all samples had high acceptability. The characteristics of beef patties containing different levels of fat and oat flour were reported by Serdaroglu (2006). Oat flour, at 0, 2 and 4% (w/w) levels were used in beef patties which had either 5, 10 or 20% fat and observed that moisture content decreased in raw patties as a result of addition of oat flour but it increased the moisture content of cooked patties. Addition of oat flour did not change the protein, fat and ash contents of either raw or cooked patties. However, it improved the cooking characteristics of patties. Oat was added by Steenblock et al. (2001) to determine the effects on the quality characteristics of light bologna and fat-free frankfurters. Different types of oat fibre like high absorption or bleached oat fibre at levels up to 3% were used. Addition of both types of fibres produced greater yields and a lighter red colour. Purge was reduced with oat fibre at 3% but product hardness increased for bologna. Modi et al. (2009) studied the development of low-fat high fibre mutton kofta using minced meat and optimized quantities of wheat flour, oat flour, carrageenan, garam masala, and salt. Inclusion of oat flour and carrageenan significantly lowered fat content and increased water, protein, ash and carbohydrates in product compared to control. Kofta containing carrageenan (0.5%) were softer in texture, had lower free fatty acids, Hunter redness and yellowness values and higher L values as compared to products without carrageenan.

Barley grain is an excellent source of soluble and insoluble dietary fibre and other bioactive constituents, such as vitamin E (including tocotrienols), B-complex vitamins, minerals, and phenolic compounds (Madhujith et al. 2006). Beta-glucans, the major fibre constituents of barley, have been implicated in lowering plasma cholesterol, improving lipid metabolism, and reducing glycaemic index (Behall et al. 2006, Keenan et al. 2007). Hydrated barley (1:3) formulation in poultry meat sausages improved juiciness and biological value by 25–30% than the control with same fat level (Titov et al. 1994). Efficacy of hull-less waxy barley and normal starch barley in ultra-low-fat pork bologna sausages was studied by Shand (2000), who concluded that hull-less waxy barley at 4% level had comparatively better purge control and water holding capacity during storage besides providing firmer texture and better sensory properties. Kumar and Sharma (2004) reported that cooking yield, moisture retention and dimensional parameters of low-fat ground pork patties increased ($p<0.05$) with increasing levels (4, 7 and 10%) of barley flour. They concluded that 4% barley flour incorporation had higher ($p<0.05$) flavour and texture scores than 7 and 10% levels.

Wheat bran is the best known source of insoluble dietary fibre. Once called roughage, this type of fibre helps to prevent and control bowel problems and is the fibre linked to lower cancer risk. Yilmaz (2005) studied the addition of wheat bran into the meatballs at levels of 5, 10, 15 and 20%. He found lower total trans fatty acids and the ratio of total unsaturated fatty acids to total saturated fatty acids was higher in the samples with added wheat bran than in the control meatballs. The wheat bran added samples were lighter and yellower than the control meatballs. Lander (2004) also reported the use of cereal fibres like *VITACEL*®, a wheat fibre, as functional ingredients in meat products such as cooked sausages, mince, raw fermented sausages and cooked ham.

Rye consumption inhibits breast and colon tumour growth in animal models, lower glucose responses in diabetics, and lowers the risk of death from coronary heart disease (Davies et al. 1999). Yilmaz (2004) studied the use of rye bran as a fat substitute in the meatballs with respect to fatty acid composition and some physico-chemical as well as sensory properties. Addition of rye bran to meatballs at 5 to 20% levels improved their nutritional value and health benefits. 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 samples with added rye bran. The same samples were lighter and yellower than the control samples. Huang et al. (2005) studied the use of rice bran in Kung-wan, an emulsified pork meatball and found that protein, fat and white index of meatballs decreased as the amount of bran increased. A texture profile analysis indicated a decrease in hardness, gumminess and chewiness of the Kung-wan. Sensory scores of taste, texture and overall acceptability of meatballs with less than 10% bran showed no significant difference from those for meatballs without bran.

Desmond et al. (1998b) investigated the effects of tapioca starch, oat fibre and whey protein on the physical and sensory properties of low-fat beef burgers. The level of tapioca starch influenced the model to the highest extent. It affected the cooking yield positively, while Warner-Bratzler and Kramer shear force were negatively influenced. The effects of both oat fibre and whey protein were found limited.

Muller and Redden (1995) studied the use of milling grade legumes as extenders in beef patties. They substituted 0–15% of beef mince with navy beans, chick peas, mung beans and red kidney beans and evaluated sensory properties, total cooking losses and proximate composition of cooked patties. Legume flours were successfully used (blackeye bean, chickpea and lentil) in meatball formulations as extenders (Serdaroglu et al. 2005). Protein content of meatballs increased with the addition of legume flours. Modi et al. (2003) reported that buffalo meat burgers containing soya bean, bengal gram, green gram or black gram dhal flours, were acceptable in terms of sensory quality when stored under frozen conditions for 4 months. Black gram flour, especially roasted, in buffalo meat burger resulted in lower fat absorption on frying and better sensory quality attributes compared to other legumes. Prinyawiwatkul et al. (1997) investigated the physico-chemical and sensory properties of chicken nuggets extended with flours processed from fermented cowpeas (FCF) and fermented partially defatted peanuts (FPDPF). They found that addition of FCF or FPDPF decreased moisture loss as well as fat gain and reduced protein content. They stated that regardless of level of FPDPF, relatively lower force and energy was required to shear the nuggets as compared to control nuggets and nuggets extended with FCF. Nuggets extended with FCF and/or FPDPF had higher redness and lower lightness, yellowness and hue angle values compared to the control but addition of 20% FCP or FPDPF caused flavour of nuggets unacceptable.

Pea hulls are particularly rich in dietary fibre, twice as much as wheat bran (Arrigoni et al. 1986). They are light coloured and tasteless, which make them interesting sources of fibre. Anderson and Berry (2001) indicated that inner pea fibre had the potential to be a useful ingredient in the development of food products required to retain the maximum amount of fat during high temperature heating. Soy hull was used by Al-Khalifa and Atia (1997) for the preparation of high fibre camel meat patties. Increased soy hull levels had significantly affected the chemical composition, calorific content, flavour, cooking yield, reduction in thickness, fat and water retention and shear force values of the products. The patties containing soybean hulls were high in fibre and low in fat and calorific content. The most acceptable meat patties were obtained with 10% fat and 6% soybean hull. Singh et al. (2008) found that chicken nuggets with roasted pea flour up to 10% levels of inclusion had significantly higher emulsion stability with a progressive but non-significant improvement in the cooking yield. Shear force value also showed a significant decrease at 10% pea flour level. Incorporation of pea flour decreased the moisture, protein and fat percent; however sensory rating of the product did not show any significant change.

Claus and Hunt (1991) studied the low fat, high added water bologna formulated with texture modifying ingredients. They incorporated Duo Fibre® (5%), oat fibre (3.5%), pea fibre (3.5%), wheat starch, Firm-tex® and isolated soy protein in dry form into 10% fat and 30% added-water bologna and reported that test bologna was less firm than the high fat control but more firm than the low fat control. They also found that fibre containing bologna were more grainy and less juicy than the high fat control.

Dietary fibres from cereals are more frequently used than those from fruits; however, fruit fibres have better quality due to higher total and soluble fibre content, water and oil holding capacity and colonic fermentability, as well as lower phytic acid content and caloric value (Figuerola et al. 2005). Epidemiological studies have pointed out that consumption of fruits and vegetables imparts health benefits, e.g. reduced risk of coronary heart disease and stroke, as well as certain types of cancer. Apart from dietary fibre, these health benefits are mainly attributed to organic micronutrients such as carotenoids, polyphenolics, tocopherols, vitamin C, and others (Schieber et al. 2001). There are many fruits, for example orange, apple, peach and olive, which are used for the extraction of their juices. They all contain a by-product from which can be recovered different high-added value compounds; among those, it is remarkable the fibre fraction that has a great potential in the preparation of functional foods. Dietary fibre concentrates from vegetables showed a high total dietary fibre content and better insoluble/soluble dietary fibre ratio than cereal brans (Grigelmo-Miguel and Martin-Belloso 1999).

Apple pulp is a typical source of dietary fibre (Goñi et al. 1989). It also contains condensed tannins - proanthocyanidin polymers and soluble polyphenols, both of which form effective cross-links with protein and inhibit digestive enzymes, thereby affecting protein digestibility (Kumar and Singh 1984, Oh et al. 1985). In an attempt to develop low salt, low fat and high fibre functional chicken nuggets, Verma et al. (2009) incorporated various dietary fibre sources like, pea hull flour, gram hull flour, apple pulp and bottle gourd in different combinations at 10% level. The products were evaluated for various physico-chemical, colour, sensory and textural properties against pre-standardized low fat chicken nuggets. There were differences in different quality attributes of control and treated products; however organoleptically treated products were comparable to control. The addition of fibre sources significantly increased the total dietary fibre content of treated products.

The use of peach dietary fibre as a fat substitute could be a good alternative to both low-fat and high dietary food products. In addition, peach dietary fibre has high water holding capacity and could help retain added water in low-fat products with no or fewer changes in textural parameters such as juiciness, springiness, tenderness, cohesiveness, and coarseness than reported in other low-fat processed meats (Gregg et al. 1993, Mittal and Barbut 1994). Grigelmo-Miguel and Martin-Belloso (1999) used two different peach dietary fibre suspensions (17 and 29%) to obtain low fat high dietary fibre frankfurters. They reported that viscosity of the meat batters increased with dietary fibre content and there was no change in protein and collagen content. Dietary fibre was effective in retaining added water in the product. The main advantage of dietary fibre from citrus fruits when compared to alternative sources of fibre such as cereals is its higher proportion of soluble dietary fibre with about 33% in citrus fruits while only 7% is present in wheat bran

(Grigelmo-Miguel and Martín-Belloso 1999, Gorinstein et al. 2001). The content of all dietary fibre fractions (total, soluble and insoluble) is higher in peels (about 65%) than in peeled citrus fruits (Gorinstein et al. 2001). The main dietary fibre fractions in citrus by-products are cellulose, lignins, pectins and hemicellulose. Fernandez- Gines et al. (2004) reported that the lemon albedo, a major component of lemon peel can be a source of dietary fibre with potential health benefits that may also improve the functional properties of meat products. Sausages containing 2.5 or 5.0% raw albedo and those containing 2.5, 5.0 or 7.5% cooked albedo had similar sensory properties to that of control sausages. Addition of raw albedo at any concentration and 2.5 or 5.0% cooked albedo increased the moisture contents of sausages and both types of albedo decreased fat content and increased protein and fibre contents.

Turhan et al. (2005) recommended use of hazelnut pellicle (obtained during roasting of hazelnut) as a suitable dietary fibre source in low-fat beef burger production. Pellicle addition was effective in improving the reduction in cooking yield, diameter and thickness of beef burgers. The effect of addition of carrot dietary fibre on the ripening process of a dry fermented sausage was studied by Valeria et al. (2008). Four formulations of a dry fermented sausage were prepared, known as sobrassada, containing different levels (3–12% w/w) of carrot dietary fibre and analyzed for physico-chemical and microbiological parameters and sensory attributes. The pH of dietary fibre supplemented sobrassadas was critically affected during ripening by the amount of dietary fibre incorporated, the values for sobrassada samples containing more than 3% of dietary fibre suggested that the fermentation process in these samples was not successful. Hardness and compression work were markedly influenced by addition of dietary fibre at higher than 3% level.

Sugarbeet fibre has also been introduced in food processing as a fibre source. Özboy-Özbas et al. (2003) recommended that the use of sugarbeet fibre as a fat substitute could be a good alternative to offer both high dietary fibre and low-fat products. However, the sensory analysis of sugarbeet fibre added frankfurters showed slightly lower scores than controls. Addition of sugarbeet fibre significantly increased the total dietary fibre content and water-holding capacity of frankfurters (Vural et al. 2004) and Turkish-type salami (Javidipour et al. 2005). Utilization of cereal (wheat and oat) and fruit (peach, apple and orange) dietary fibres, at 1.5 and 3% concentrations in low fat dry fermented sausages was reported by García et al. (2002). The energy value reduction of the final products was close to 35% and their final fibre contents, after ripening, were 2 and 4%, respectively. Sensory and textural properties of sausages with 3% dietary fibre were not good, due to their hardness and cohesiveness. The best results were obtained with sausages containing 1.5% fruit fibre especially those with orange fibre, which gave organoleptic characteristics similar to conventional high fat products. Aleson-Carbonell et al. (2005) studied the functional and sensory effects of fibre-rich ingredients on breakfast sausages. They used citrus (lemon) fibre extract and beta-glucan rich ingredients (from oats) as extenders in addition to conventional wheat rusk and compared the samples without fillers (control) and samples extended with the ingredients, alone or in combination at 7% level. Addition of any of these ingredients (alone or in combination) reduced cooking loss and shrinkage and increased lightness of cooked sausages. They also found that sausages containing oat and wheat rusk or combination of oat, wheat rusk and lemon albedo had the highest overall acceptance score.

Some components of dietary fibre are the fructooligosaccharides (FOS), a generic name for all non-digestible oligosaccharides composed mainly of fructose. The effect of a short-chain FOS on cooked sausages was studied by Cáceres et al. (2004). The energy values decreased from 279 kcal/100 g in the conventional control to 187 kcal/100 g in the reduced-fat sausages with 12% added fibre. The hardness of the samples with soluble dietary fibre was lower, and the overall acceptability in the sensory analysis was higher in samples with 12% fibre. Another soluble dietary fibre is inulin, which can be used as a fat substitute because of its contributions to better mouthfeel, enhanced flavour, and low-caloric value (1 kcal/g). Mendoza et al. (2001) reported the use of inulin as a fat substitute in low fat, dry fermented sausages. Sensory properties were similar to that of conventional high fat sausage and with the addition of inulin (about 10%), a low (30% of the original) calorie product was obtained. The effect of inulin on the textural and sensory properties of mortadella, a Spanish cooked meat product, was also studied by García et al. (2006). Inulin was incorporated as powder and gel. Powdered inulin increased the hardness of reduced fat sausages even at 2.5% level while inulin in the form of gel affected textural parameter of product only at 7.5% level. However, the sensory properties remained similar for all products but inulin in gel form was preferred. Yilmaz and Gegel (2009) found that veal meatballs containing inulin had lower concentrations of total fat and total trans fatty acids than the control samples. Meatballs with 20% inulin had highest ash, protein, lightness, yellowness and lowest moisture, salt, weight losses and redness. Sensory scores of meatballs with 10, 15 and 20% added inulin were less acceptable due to hardness, low juiciness, and low flavour intensity. Incorporation of inulin at 5% level was found optimum in veal meatballs.

Future perspective

The dietary fibre from various sources like cereals, legumes, fruits and vegetables and their by-products can be incorporated in different meat products to make them more nutritious, healthier as well as consumer oriented. However, some fibre sources affect physico-chemical, sensory and textural properties of meat products when added in excess amount. With regard to products quality, fruit fibres have been found more desirable compared to cereals (García et al. 2002). The sensory attributes of the products remain equally acceptable when different fibre sources were incorporated in judicious combinations even at higher level (Verma et al. 2009). Thus, many agro-industrial by-products can be sensibly incorporated in meat products to improve their health benefits. Further research could be carried out to explore other vistas to maintain different quality attributes and desirability as well.

Conclusion

The incorporation of dietary fibres, 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 fibre 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 fibre have been explored by different researchers, which are being attempted in the meat products. These sources markedly enhance the dietary fibre content in meat products and making them more functional as well as healthier. The meat products can be enriched with adequate amount of dietary fibre by wise selection of fibre 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.

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