

Functionality and Application of Dietary Fiber in Meat Products

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Abstract

Dietary fiber naturally present in various sources of cereals, legumes, fruits and vegetables plays a physiological role in human health, such as lowering cholesterol and blood pressure, improving blood glucose control in diabetes, helping with weight loss and management, and reducing cancer risk. In addition, dietary fibers have been added as a functional food ingredient to food products to provide water-holding capacity, viscosity, gel-forming ability, and fat-binding capacity to food products. These beneficial characteristics of dietary fiber components can improve the image of meat products to be healthy and functional food products. This article reviews the concept and current definition of dietary fibers in food products along with their health benefits and functional characteristics. Dietary fibers from different sources like cereals, legumes, fruits, and vegetables and soluble dietary fibers have been applied as functional ingredients to various types of meat products, such as beef patties, ground beef and pork, pork and chicken sausages, meatballs, and jerky etc. Based on the application of dietary fibers to different types of meat products, possible future characteristics in selecting appropriate dietary fiber ingredients and their proper incorporation are explored to develop and produce healthy and functional meat products with high dietary fiber contents.

Key words: dietary fiber, meat product, functional property

Introduction

Dietary fiber is the non-digestible form of carbohydrates and lignin. Consumption of dietary fiber provides a feeling of fullness and promotes healthy laxation (Anderson *et al.*, 2004). Specially, increased consumption of dietary fiber lowers serum lipid concentrations and blood pressure, improves blood glucose control in diabetes, and aids in weight loss by increasing satiety (Anderson *et al.*, 2004; Anderson *et al.*, 2009; Keenan *et al.*, 2002). Current recommendations for dietary fiber intake are 25 g/d for women and 38 g/d for men in the United States (USDA, 2010) and 20 g/d for women and 25 g/d for men in Korea (KNS, 2010). However, most people consume less than half the recommended level of dietary fiber daily regardless of the widely acknowledged nutritional health benefits of dietary fiber consumption. The growing interest of consumers and food scientists about dietary fiber has encouraged developing high-fiber food products that provide the recommended level of dietary fiber.

Meat and meat products have both positive and negative effects on health in the diet. They are important sources of protein and essential amino acids with high biological value and essential fats, vitamins A and B, and minerals (Biesalski, 2005). However, meat and meat products are often considered negative due to high levels of saturated fats, cholesterol, sodium, and nitrite (Jimenez-Colmenero *et al.*, 2001). Some of these negative aspects in meat and meat products could be reduced by selection of lean meat cuts, removal of fats and cholesterol, dietary feed supplementation to alter fatty acid composition and decrease fat and cholesterol contents of meat, and replacement of sodium and nitrite (Decker and Park, 2010). In addition, the nutritional profile of meat products could be further improved by addition of potentially health promoting ingredients. Dietary fiber as a functional ingredient can be incorporated with meat products to improve health view of meat products. The addition of dietary fiber to meat products has been successfully used in improving cooking yield, reducing fat contents, and enhancing texture (Cofrades *et al.*, 2000; Mendoza *et al.*, 2001). Various types of dietary fibers have been studied for formulations of meat products such as frankfurters, dry fermented sausages, and beef patties (Chang and Carpenter, 1997; Men-

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doza *et al.*, 2001; Pinero *et al.*, 2008). The objective of this article was to review sources, health benefits, and functional properties of dietary fibers as functional ingredients along with their application to meat products.

Dietary fiber

Dietary fiber has highly complex substances that can be described as any non-digestible carbohydrates and lignin not digested in small intestine. The definition of dietary fiber has been revised several times since it was first defined by Hipsly in 1953 (Buttriss and Stokes, 2008). The widely accepted definition by the American Association of Cereal Chemists (AACC) states: "Dietary fiber 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 fiber includes polysaccharides, oligosaccharides, lignin, and associated plant substances. Dietary fibers promote beneficial physiological effects including laxation, and/or blood cholesterol attenuation, and/or blood glucose attenuation" (AACC, 2001). This definition provides a balance between the analytical methods used to quantify dietary fiber in foods and the biological and physiological effects of fiber.

Dietary fiber is available in the human diet through a wide variety of food sources, such as both raw and pro-

cessed cereals, legumes, fruits and vegetables (Table 1). It is important to understand the functional attributes of the various available fiber sources. In order to better understand the functional properties of dietary fiber, it is helpful to categorize the dietary fibers into groups. Dietary fibers are classified by their relative solubility in water. Fibers that are composed of cellulose, hemicellulose, and lignin are primarily insoluble and those that include substantial portions of gums, polysaccharides, and pectin are soluble dietary fiber. Depending on their solubility, the physiological effects of dietary fibers are different (Fig. 1). Soluble dietary fibers produce viscous solutions that delay gastric emptying and absorption from the small intestine and tend to lower blood cholesterol level and

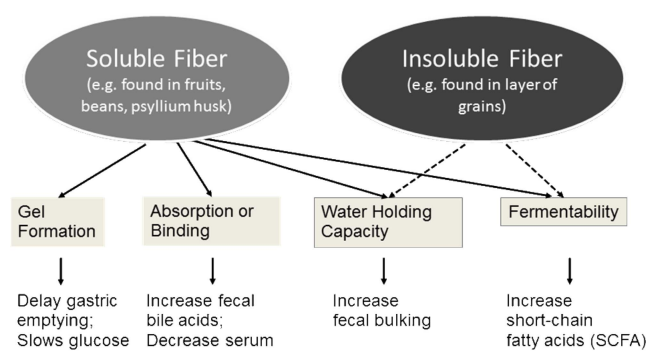


Fig. 1. Soluble and insoluble dietary fiber and their physiological functions.

Table 1. Most common dietary fibers, their primary sources and reported health benefits^a

Dietary fiber components	Fiber sources	Health benefits
Cellulose	Primary component of the cell walls of most plants. Grains, fruits, vegetables, and nuts.	Laxation
Hemicellulose	Forms about a third of the fiber in vegetables, fruits, legumes, and nuts. Main dietary sources are cereal grains.	Laxation
Pectin	Found in cell walls and intracellular tissue of fruits and vegetables. Sugar beets and potatoes are major sources.	Blood lipid lowering Attenuates blood glucose response
Beta-glucan	Oats, barley	Blood lipid lowering Attenuates blood glucose response
Resistant starch	Legumes, unripe banana	Laxation Attenuates blood glucose response
Inulin Fructooligosaccharides	Chicory root, Jerusalem artichoke, synthesized from simple carbohydrates	Laxation Blood lipid lowering
Gums	Gum guar, gum arabic, agar, carageenans, alginates	Blood lipid lowering Attenuates blood glucose response May promote gut health
Psyllium	Psyllium husk (plant)	Laxation Blood lipid lowering
Chitin/Chitosan	Fungi and shellfish	Blood lipid lowering
Lignin	Woody plant	

^aCited from Anderson *et al.*, 2009; Buttriss and Stokes, 2008; Tunland and Meyer, 2002

glucose response (Anderson *et al.*, 2004). Insoluble dietary fibers more help to accelerate rather than delay small bowel transit and have greater laxative effect than soluble fibers do (Anderson *et al.*, 2004).

Dietary fiber for health

High-fiber diets have been associated with many health benefits such as lowering serum lipid concentration and blood pressure, helping with weight management, improving glucose and insulin response, maintaining a healthy digestive system, and reducing cancer risk (Buttriss and Stokes, 2008; Lattimer and Haub, 2010). Three physiological effects including laxation, blood cholesterol reduction, and glucose attenuation have been demonstrated for high-fiber diets over the past years. However, not all of the dietary fibers are able to perform each of these characteristics as shown in Table 1.

Digestive health

Dietary fiber components are not digested in the small intestine of humans. They are completely or partly fermented by the colonic microflora in the large intestine. Fermentation of dietary fiber components results in the formation of gases such as hydrogen, methane, and carbon dioxide and short-chain fatty acids (SCFA), primarily acetate, propionate, and butyrate. The available dietary fiber substrate in the colon results in the increase in the number of bacteria and in fecal mass. Increased fecal bulk helps to reduce colonic transit time which prevents constipation. The production of SCFA from the fermentation of dietary fiber components plays a key role in the health of colon. Propionate, in particular, was reported to lower cholesterol by suppressing cholesterol synthesis in the liver (Nishina and Freedland, 1990). Also, butyrate is the preferred sources for the growth and differentiation of colonic cells and possibly inhibits tumor growth (McIntyre *et al.*, 1993). The formation of SCFA decreases the pH in the gut and thereby inhibits the growth of harmful bacteria while aiding the growth of bifidobacteria and lactic acid microflora (Scott *et al.*, 2008).

Cardiovascular health

Intake of dietary fiber at recommended daily level is associated with lowering the risk of coronary heart disease, stroke, and peripheral vascular disease (Liu *et al.*, 2000; Mann, 2007; Merchant *et al.*, 2003). The mechanisms for the lowering effect of cardiovascular disease from the consumption of dietary fiber are unclear, but it is

suggested that some dietary fiber, such as β -glucan, guar gum, pectin, and psyllium, can reduce blood cholesterol levels by lowering the reabsorption of bile acids and increasing fecal excretion of bile acids (Drzikova *et al.*, 2005). Bile acids are synthesized in the liver from cholesterol. By binding bile acids with dietary fiber components, cholesterol in the liver can be converted to additional bile acids which are excreted, thus lowering cholesterol (Lunn and Buttriss, 2007).

Prevention of diabetes

Dietary fiber intake is inversely associated with risk of developing type 2 diabetes. Many studies reported a protective effect by whole grain foods (Mann, 2007; Venn and Mann, 2004). The protective effect resulted from the ability of dietary fiber to lower post-prandial glucose response (Meyer *et al.*, 2000). Individuals consuming a diet with a high glycemic index (GI) and a low intake of cereal fiber have a risk of developing type 2 diabetes compared to those consuming a high-fiber diets with a low GI (Schulze *et al.*, 2004).

Prevention of obesity

Food rich in dietary fiber help to promote satiety and a sense of fullness because of a high volume and a low energy density, thus preventing obesity (Buttriss and Stokes, 2008). Tucker and Thomas (2009) reported that the middle aged women consumed greater amounts of dietary fiber lost their weight caused by the decrease of body fat. The loss of weight was related to the intake level of dietary fiber in cereals, fruits and vegetables, and whole grains (Du *et al.*, 2010; Koh-Banerjee *et al.*, 2004; Tucker and Thomas, 2009). There is some evidence that several mechanisms may be involved like effects by gastric emptying, transit time to small intestine, and gut hormone production and these mechanisms may be influenced by types of dietary fiber (Buttriss and Stokes, 2008).

Functional characteristics of dietary fiber

Along with health and nutritional benefits, dietary fiber has various suitable functional properties which affect the quality and characteristics of food products. These functional properties should also be considered when various sources of dietary fiber incorporated to meat products. The major functional properties of dietary fiber are water-holding capacity, viscosity, gel-forming ability, and fat-binding capacity.

Water-holding capacity

Dietary fiber generally has a high water-holding capacity. By hydrating a fiber, the water occupies the fiber pores and increases cooking yields, possibly reducing the caloric contents of meat products. Moreover, a high water-holding capacity can control moisture migration and ice crystal formation so that increasing the stability during freezing and thawing process (Gelroth and Ranhotra, 2001). The length, particle size, and porosity of dietary fiber components may affect the water-holding capacity and these can contribute to mouthfeel of the final products (Gelroth and Ranhorta, 2001; Tunglund and Meyer 2002). The longer fibers which impart increased capability of water-holding to meat products can result in changes in texture depending on the level of fiber. The length and water-holding capacity of fiber is thus balanced against the textural changes (Bodner and Sieg, 2009).

Viscosity

Viscosity is a very important role of dietary fiber, providing rheological properties in food system including meat products. As the molecular weight or chain length of the fiber increases, the viscosity of fiber in solution increases. Long chain polymers, such as guar gum, locus bean gum, and β -glucan, exhibit high viscosity in the solution and these are used as thickening agents at low concentrations. Highly soluble fibers which have low viscosity, such as gum arabic, inulins, and oligosaccharides, are generally used to modify texture and water migration and to improve the marketability of the meat products as health-promoting or functional food products (Tungland and Meyer, 2002).

Gel-forming ability

The gel-forming ability of dietary fiber ingredients can contribute to increase the thickness or viscosity of products. Gelation is the association of polymer units to form a gel network with a firm three dimensional structure (Tungland and Meyer, 2002). This structure may stabilize or modify the physical structure of meat products thus helping to minimize shrinkage and improve product density. The composition and chemical properties provided by the various sources of dietary fiber can impact significantly on the ability of fiber to function as gelling agents. Blending of different sources of dietary fibers can also perform to develop a product specifically suited to the needs.

Fat-binding capacity

Alone or the combination of two or more dietary fiber

ingredients can be used to reduce fat content in meat products (Decker and Park, 2010; Weiss *et al.*, 2010) because they are fat dispersible and some also bind. The addition of dietary fiber ingredients that exhibit emulsion, lubricity, and gel texture can successfully replace some portion of fat in meat products.

Application of dietary fiber in meat products

As previously noted, dietary fiber provides various functional characteristics to food products along with health benefits. Dietary fiber as a functional ingredient is applicable to meat products (Table 2). Many studies reported that dietary fiber were incorporated with different types of meat products to increase cooking yield and reduce fat contents due to their water-holding and fat-binding properties (Garcia-Garcia and Totosau, 2008; Yilmaz, 2005). Dietary fiber from various sources alone or combined with other ingredients were formulated to low-fat and sodium-reduced meat products, largely ground and restructured meat products (Berain *et al.*, 2011; Garcia-Garcia and Totosau, 2008; Kumar and Sharma, 2004).

Fibers from cereals

Most usable dietary fiber sources for meat products were obtained from cereals, such as wheat, oat, rye, and rice (Table 2). Oats are well recognized as a whole-grain cereal, highly recommended as an important part of the daily diet. The use of oat fiber has gained a very positive attention to consumers because of health benefits associated with its consumption. Health benefits of oat-based food products are attributed to the soluble dietary fiber in oats, (1 \rightarrow 3), (1 \rightarrow 4)- β -D-glucan, referred to as β -glucan. The consumption of β -glucan attenuate postprandial glycemia, lowers cholesterol in the blood, and reduces colonic cancer risk (Butt *et al.*, 2008; Lazaridou and Biliaderis, 2007). The U. S. Food and Drug Administration (FDA) has thus allowed a health claim stating that oat β -glucan at a level of 0.75 g per serving in a product, equal to a level of 3 g/d, may reduce cholesterol and lower the risk of coronary heart disease (FDA, 1997). These health benefits may be caused by the increase in viscosity formed by β -glucan, which is related to its concentration, structure, and molecular weight (Wood *et al.*, 2000). Processing and cooking methods possibly influence the molecular, structural, and functional properties of β -glucan. Processing methods improved the physiological activity of β -glucan by increasing solubility and extractability (Regand *et al.*, 2009) and reducing the molecular size of

Table 2. Recent research articles about meat products containing dietary fiber as functional ingredients

Food groups	Dietary fiber	Meat product	Impact on product	Reference	
Cereals	Oat flour	Beef patties Cooked chicken kofta	Increase moisture content and cooking yield Reduce fat	Serdaroglu, 2006 Prasad <i>et al.</i> , 2011	
	Oat fiber	Pork sausages Sausages Chinese-style sausages	Improve flavor, texture, mouthfeel Substitute fat Improve hardness, 3.5% inclusion optimum for sensory	Desmond and Troy, 2003 Szezepaniak <i>et al.</i> , 2005 Huang <i>et al.</i> , 2011	
	Oat bran	Chicken meat patties	Improve WHC, emulsion stability	Talukder and Sharma, 2010	
	Oat β -glucan	Beef patties	Substitute fat, improve cooking yield, moisture retention	Pinero <i>et al.</i> , 2008	
	Hydrated oatmeal	Italian sausage Pork sausage Pork sausage	Reduce fat, cook loss, and hardness, lighten color Improve texture quality Reduce fat and cooking loss, improve WHC and texture	Kerr <i>et al.</i> , 2005 Yang <i>et al.</i> , 2007 Yang <i>et al.</i> , 2010	
	Barley flour	Pork bologna Pork patties Pork sausage	Improve WHC, texture, and sensory Improve WHC, cooking yield, and sensory Reduce fat	Shand, 2000 Kumar and Sharma, 2004 Choi <i>et al.</i> , 2011	
	Wheat fiber	Sausages Frankfurter sausage Chinese-style sausage	Reduce fat Reduce cooking loss, increase emulsion stability Improve texture	Szezepaniak <i>et al.</i> , 2005 Kim <i>et al.</i> , 2009 Huang <i>et al.</i> , 2011	
	Wheat bran	Meatballs Cooked beef patties Chicken meat patties	Reduce total fat and trans fatty acids Reduce fat Improve WHC and emulsion stability	Yilmaz, 2005 Sarıcoban <i>et al.</i> , 2009 Talukder and Sharma, 2010	
	Corn bran	Turkish meatballs	Reduce cooking loss, 10% corn bran acceptable for sensory	Yasarlar <i>et al.</i> , 2007	
	Rye bran	Meatballs	Substitute fat (5-20% level), improve nutritional value and health benefits, reduce total trans fatty acids, lighten color	Yilmaz, 2004	
Legumes	Rice bran	Meat batters Frankfurter sausage Semi-dried pork jerky Ground pork	Reduce cooking loss, improve emulsion stability Estimated shelf-life was not different with control Reduce cooking loss, improve texture Reduce fat	Choi <i>et al.</i> , 2007 Heo <i>et al.</i> , 2009 Paik <i>et al.</i> , 2010 Kim <i>et al.</i> , 2011	
	Legume flour	Meatballs	Reduce fat, increase protein	Serdaroglu <i>et al.</i> , 2005	
	Pea flour	Bologna	Reduce fat, cooking and purge losses, increase WHC	Pietrasik and Janz, 2010	
	Pea fiber	Beef patties Chicken nuggets	Improve WHC, cooking yield, and sensory quality Improve emulsion stability and sensory quality	Beshes <i>et al.</i> , 2008 Singh <i>et al.</i> , 2008	
	Locust bean gum	Sausages	Reduce moisture and cooking loss, increase shelf-life	Dlek <i>et al.</i> , 2011	
	Apple pulp	Chicken nuggets	Improve emulsion stability and cooking yield	Verma <i>et al.</i> , 2010	
	Lemon albedo	Bologna sausages Sausages	Improve cooking yield, sensory Reduce cooking loss and shrinkage, lighten color	Fernandez-Gines <i>et al.</i> , 2004 Aleson-Carbonell <i>et al.</i> , 2005	
	Grape fiber	Chicken breast patties	Prevent lipid oxidation	Sayago-Ayerdı <i>et al.</i> , 2009	
	Carrot fiber	Dry fermented sausage Pork sausages	Improve texture Improve emulsion stability and texture	Eim <i>et al.</i> , 2008 Grossi <i>et al.</i> , 2011	
	Tomato fiber	Cooked chicken	Improve emulsion stability, reduce lipid oxidation	Cava <i>et al.</i> , 2012	
Soluble fibers	Inulin	Water-boiled sausage Fish sausage Chinese-style sausages Fermented sausage	Reduce fat from 43 to 52% without loss of sensory quality Improve gel strength and hardness No influence on the texture 7.5% and 15% inulin replace fat	Hadam <i>et al.</i> , 2007 Cardoso <i>et al.</i> , 2008 Huang <i>et al.</i> , 2011 Sun <i>et al.</i> , 2010	
	Short-chain FOS	Dry fermented sausage	Increase FOS amount from 2, 4, and 6%, lighten color	Salazar <i>et al.</i> , 2009	
	Pectin	Sausages Cooked ham	Natural emulsifier, reduce hardness and pH Sensory accepted for high blood pressure patients' diet	Pereira <i>et al.</i> , 2010 Cardoso <i>et al.</i> , 2012	
	Pectin + alginate	Pork sausages	Pectin for casings, alginate for gelation	Liu <i>et al.</i> , 2007	
	Alginate	Sausages	Reduce fat	Berain <i>et al.</i> , 2011	
	Carrageenan	Turkey meat sausages Frankfurter sausage	Improve WHC, emulsion stability, texture Reduce fat	Ayadi <i>et al.</i> , 2009 Cierach <i>et al.</i> , 2009	
	Locust bean gum, carrageenan	Sausages	Improve cooking yield, texture and water retention	García-García and Totosaus, 2008	
	Carrageenan, gellan gum, flaxseed gum	Sausages	Improve WHC and texture, lighten color	Zhou <i>et al.</i> , 2008	
	Others				

the polymer (Izydorczyk *et al.*, 2008).

Due to the potential health benefits of oat fiber, especially β -glucan, it has been interested in using as a functional ingredient in common meat products. Functional characteristics of oat fiber, especially water-holding capacity, could potentially benefit meat products to decrease cooking losses and reduce fat content without loss of sensory acceptability in meat products, such as beef patties, pork sausages, and meatballs (Serdaroglu, 2006; Yasarlar *et al.*, 2007; Yilmaz and Daglioglu, 2003). Different types of oats were added to different meat products. Oat flour itself was added to determine the characteristics of beef patties at 2 and 4% (w/w) levels (Serdaroglu, 2006). The results indicated that oat flour at 4% addition helped to improve the cooking characteristics of beef patties without loss of sensory properties. Talukder and Sharma (2010) developed fiber-rich chicken meat patties containing 10 and 15% level of fiber by incorporated with oat bran. The addition of oat fiber provided the flavor, texture, and mouthfeel in pork sausages (Desmond and Troy, 2003). Pinero *et al.* (2008) utilized oat soluble fiber β -glucan. They added β -glucan (13.45%) by using a commercial food product, called Nutrim-10®, to low-fat (<10% fat) beef patties and compared physical, chemical, microbiological and sensory properties with control beef patties (20% fat). The results showed that the addition of β -glucan improved cooking yield and fat retention and the water-holding capacity of β -glucan attributed to reach moisture content high in beef patties. Low-fat beef patties prepared with β -glucan lowered the degree of likeness in the taste but maintained the uniform tenderness without any noticeable loss of microbiological quality under frozen storage for 60 d in addition to providing physiological benefits of β -glucan. In the studies of Kerr *et al.* (2005) and Yang *et al.* (2007, 2010), hydrated oatmeal and oat flake were successfully incorporated to prepare low-fat pork sausages with optimum level of 15% to have sensory acceptability.

Barley is another excellent source of insoluble dietary fiber and soluble dietary fiber including β -glucan (Izydorczyk and Dexter, 2008). Because of health benefits of β -glucan, barley flour was incorporated to pork sausages (Choi *et al.*, 2011; Shand, 2000). Kumar and Sharma (2004) reported that cooking yield, moisture retention, and dimensional parameters of low-fat ground pork patties were improved with increasing barley flour levels at 4, 7, and 10% and concluded that 4% inclusion of barley flour had greater sensory flavor and texture scores than 7 and 10% levels.

Bran is the outer most layers of a cereal grain and has

shown to decrease postprandial glucose levels, serum cholesterol, and colon cancer risk and to control body weight (Lattimer and Haub, 2010). Wheat bran, known as the best source of insoluble dietary fiber, was used as a fat substitute in the production of meatballs and beef patties (Saricoban *et al.*, 2009; Yilmaz, 2005). Chicken meatballs prepared with wheat bran at 5, 10 and 15% levels increased cooking yield and firmness as well as insoluble fiber content (Talukder and Sharma, 2010). Saricoban *et al.* (2009) optimized processing variables including fat (10-30%), wheat bran (5-15%), and sodium chloride (0-2%) of cooked beef patties by using response surface methodology. In the study of Yilmaz (2004), rye bran was added to meatballs as a fat substitute. The addition of rye bran at the levels of 5, 10, 15, and 20% improved their nutritional value and reduced total fat including *trans* fatty acids. Another source of bran incorporated to meat products is rice bran. Choi *et al.* (2007) reported that meat batters containing rice bran had high pH values but lowered cooking loss and improved emulsion stability. Similar effects were also reported with semi-dried pork jerky and raw ground pork (Kim *et al.*, 2011; Paik *et al.*, 2010). Heo *et al.* (2009) investigated the growth of microorganisms related to spoilage in frankfurter sausage containing rice bran at 0, 1, 2, and 3% to estimate the shelf-life of sausage. The addition of rice bran in sausage did not show significant differences in shelf-life as indicating no critical hazardous results in the growth of microorganisms caused by the addition of rice bran fiber.

Fiber from legumes

Legumes are important diet constituents, providing proteins and dietary fiber. Soybean and pea fiber have similar properties related to the fibers and are available either from their outer hulls or cotyledon portion. The extracted fibers from soybean and pea hulls are shorter and more cube-like rather than long thread-like structures observed in oat and wheat fiber (Bodner and Sieg, 2009). As a result, the water absorption capability of soybean and pea fiber tends to be lower than oat and wheat fiber. Pietrasik and Janz (2010) utilized pea starch and pea fiber-rich fractions to reduce fat contents of bologna sausage. The use of pea fibers as meat replacement in beef patties improved water-holding capacity so that increased cooking yield and minimized the production cost without degradation of sensory properties (Besbes *et al.*, 2008). Roasted pea flour up to 10% level was incorporated to produce chicken nuggets and helped to improve emulsion stability without loss of sensory acceptability (Singh *et*

et al., 2008). Legume flours from blackeye bean, chick pea and lentil were successfully incorporated in production of meatballs with increased protein content (Serdaroglu *et al.*, 2005).

Fiber from fruits and vegetables

Consumption of fruits and vegetables can help to prevent heart disease and stroke, control blood pressure, and prevent some types of cancer. These health benefits are mainly attributed to organic micronutrients such as fiber, carotenoids, polyphenols, tocopherols, vitamin C, and other minor components (Schieber *et al.*, 2001). During the processing of fruits and vegetables, abundant waste materials are produced and these by-products can be recovered and become high-added value products. Dietary fiber fractions of fruits and vegetable by-products have a great potential in the preparation of meat products as health promoting functional foods. Apple pulp was incorporated to prepare low-fat chicken nuggets at the levels of 8, 10 and 12% (Verma *et al.*, 2010). The pH of the chicken nugget product was lower than that of control but the addition of apple pulp significantly improved emulsion stability and cooking yield. The dietary fiber from citrus fruits contains high proportion of soluble dietary fiber so that used for meat products to promote health benefits. The important consideration when formulating meat products with citrus fibers is the taste profile because of its low pH which can cause acidic or bitter taste (Bodner and Sieg, 2009). Fernandez-Gines *et al.* (2004) successfully incorporated lemon albedo at 2.5 and 5% to sausages which had similar sensory properties to control sausage. The addition of grape antioxidant dietary fiber at the levels of 0.5, 1, 1.5, and 2% to chicken breast hamburger decreased lightness and yellowness and increased in redness when cooked (Sayago-Ayerdi *et al.*, 2009). When tomato fiber was incorporated in chopped cooked chicken products, the pH of chicken batters reduced in proportional to the level of fiber addition (1, 2, and 3%) and increased the redness of chicken product (Cava *et al.*, 2012).

As a vegetable fiber, carrot fiber is a relatively new fiber to find the application in meat products and it has very high water absorption capability. Eim *et al.* (2008) formulated a dry-fermented sausage containing carrot dietary fiber at the levels of 3 to 12%(w/w) and more than 3% fiber inclusion were not successful to have firm texture. In the study of Grossi *et al.* (2011), high pressure technology applied to the pork sausage incorporated with carrot dietary fiber. High pressure treatment and carrot

fiber inclusion improved emulsion strength resulting in firm sausages but color was slightly changed.

Soluble dietary fibers

The functionality and application of soluble fibers in meat products include a wide range of fiber ingredients such as methylcellulose, carboxymethyl cellulose, hydrocolloid ingredients like xanthan and acacia gums (Bodner and Sieg, 2009). Inulin is a soluble fiber extracted by a washing process from chicory roots. It contains oligosaccharides and polysaccharides composed of fructose connected by β -(2 \rightarrow 1) glycosidic bonds. Inulin added to meat products is mainly used for fat replacement because it forms a stable gel network which can mimic some textural properties of fat in low-fat meat products. By substituting fat with inulin for low-fat processed meat products, it is possible to achieve acceptable textural and sensory properties (Hadorn *et al.*, 2007; Sun *et al.*, 2010). Cardoso *et al.* (2008) formulated fish sausages containing chicory root inulin with the improvement of texture.

Another soluble dietary fiber used for meat products is fructooligosaccharides (FOS), recognized as a natural food ingredient and considered as a prototype pre-biotic which stimulates the growth of colonic microflora (Flamm *et al.*, 2001). The effect of short-chain FOS on color, textural, and sensory properties in dry-fermented sausages was studied (Salazar *et al.*, 2009). Physicochemical properties and microbial evolution during ripening of sausage were not affected by the presence of short-chain FOS but color was lighter than control. The presence of FOS reduced hardness of dry-fermented sausages to be easier to chew.

Other than those dietary fiber components, different fiber sources and their mixtures were incorporated into meat products. For examples, carrageenan and alginate from seaweeds were added to turkey meat sausages, pork sausages, and frankfurters with enhanced emulsion stability of products (Ayadi *et al.*, 2009; Beriain *et al.*, 2011; Cierach *et al.*, 2009). In the study of Zhou *et al.* (2008), carrageenan, gellan gum and flaxseed gum were added together to produce starch-free emulsion-type sausage and the optimal contents of carrageenan, gellan gum, and flaxseed gum in the mixture for the sensory quality were 11-27%, 67-82%, and 0-12%, respectively.

Future Prospects

Dietary fiber from various sources, such as cereals, legumes, fruits and vegetable, can be successfully formu-

lated to different types of meat products to improve nutritional values through fiber enrichment and fat reduction and to increase consumer acceptance. However, it is unclear if added dietary fiber to meat products provides the same health benefits as naturally occurring sources. In addition, bioavailability of added dietary fiber ingredients should be maintained during the processing and storage of meat products. Most conclusions are drawn from the fact that dietary fiber itself is beneficial to human health. Many studies only investigated the formulation of dietary fiber to produce final meat products. Therefore, further studies are needed to provide strong evidences to show the physiological effects of dietary fiber ingredients from different sources when formulated and processed meat products.

Conclusion

Dietary fiber has been used for food products because of their health benefits such as lowering serum lipid concentration, reducing glucose and insulin response, helping with weight management, maintaining a healthy digestive system, and reducing cancer risk. The addition of dietary fiber to meat products was considered to be health beneficial, thus possibly leading well-being of consumers. Moreover, functional characteristics of dietary fiber, mostly high water-holding capacity and fat-binding capacity, promoted their incorporation to meat products. Various sources of dietary fiber have been explored to formulate different types of meat products. The addition of dietary fiber enriched total dietary fiber content and reduced fat contents in meat products. The results suggested that dietary fiber can be used to meat products with their health benefits and functional properties. Further research is needed to understand their physiological effects not only when formulated but also during processing and storage.

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