Agronomy Research **17**(X), xxx–ccc, 2019
https://doi.org/10.15159/AR.19.163

Enrichment of meat products with dietary fibers: a review

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Abstract. In recent years, much attention has been paid to the development of food products with properties that can promote well-being and prevent disease. Tested strategies to improve the functional value of meat products through the introduction of dietary fiber are reviewed here. Based on the literature reviewed, the addition of dietary fiber in meat products contributes to the fabrication of products which enhance physiological functions. Furthermore, fibers can be used to improve the quality and yield of meat products.

Key words: dietary fiber, meat product, health, functional value.

INTRODUCTION

The meat industry is one of the most important in the world. One of the directions, for the development of the meat industry, is the production of healthy foods characterized by a lower fat content. This development also includes the enhancement of meat products to achieve a higher content in minerals, vitamins, antioxidants or dietary fibers (Cofrades et al., 2008; Zhang et al., 2010; Bis-Souza et al., 2018).

Dietary fibers are recognized to have an important physiological role in the human body. For this reason, dietary fibers are considered before other nutrients to ensure a healthy nutrition. The lack of fibers in the diet is often associated with gastrointestinal diseases, including constipation, colon cancer; increased risks of cardiovascular diseases, including hypercholesterolemia, stroke, and ischemic heart; metabolic diseases, including obesity and diabetes (Jimenez-Colmenero et al., 2001; Fuller et al., 2016).

The fat content significantly affects organoleptic characteristics of meat products. This is because fat has binding properties and contribute to juiciness, tenderness and taste (Mallika et al., 2009). For example, in sausages, it was noted that a low fat content reduces the taste and texture qualities of foods (Choi et al., 2011). Various dietary fibers have, therefore, been used to improve the texture of meat products with a low fat content

(Pintado et al., 2016). The addition of dietary fibers was shown to improve texture properties by Schmiele et al. (2015) and Bis-Souza et al. (2018). Replacing fats with dietary fibers contributes to lowering the calorie content of meat products (Hu et al., 2015).

The recent increased consumer interest in healthy and low fat nutrition, opens the door to the development of a large market for fiber-rich foods. The purpose of this study is to review the actual information on dietary fibers application in the formulations of fortified meat products as well as analysis of their effects on technological properties of meat.

SPECIFICATION OF DIETARY FIBERS

Dietary fibers are generally known as the indigestible portion of food. In fact, the term 'dietary fiber' was first used in an article by Hipsley (1953). Trowell et al. (1985) defined dietary fiber as 'the sum of polysaccharides and lignin not digested by the human gastrointestinal tract'. Later, Jimenez-Colmenero et al. (2001) defined dietary fibers as carbohydrate food components which are not hydrolyzed by the endogenous enzymes in the small intestine.

It is also known that diverse types of fibers have different properties within the gastro-intestinal track such that it is challenging to come up with a definition that encompasses all aspects. Zielinski & Rozema (2013) reviewed the definitions of 'dietary fiber', used by the Institute of Medicine, AACC International and Codex Alimentarius Commission and noted one commonality in these definitions: each mentioned positive physiological effects. This reflected that, in the international scientific community, the importance of dietary fibers in human nutrition was increasingly recognized.

Although the definition of dietary fibers is still elusive, Fuller et al. (2016) point to dietary fibers' modes of action being related to chemical compounds defined by structure, or functional properties, and/or a combination of both structural and functional properties. The various classifications methodologies used to describe dietary fibers reflect such a complexity.

Different characteristics can be used as a basis for the classification of dietary fibers. The type of raw material, the structure of polymers, the amounts and proportions of raw materials and of co-agents, the ability to dissolve in water and water binding capacity can be used to classify dietary fiber. Other characteristics such as the ion exchange, sorption or physiological properties have also been used to classify dietary fibers. The most common classification strategies are described below.

USE OF DIETARY FIBERS IN MEAT PRODUCTS TECHNOLOGIES

Dietary fibers come from grains, vegetables, fruits, and enriched preparations of food products. Traditional sources of fibers and β-glucan in the diet are cereals, such as wheat, oats and barley (Sze et al., 2017). Fruits, vegetables, legumes, soy, psyllium husk and oat bran are good sources of SDF while whole grains are good sources of IDF (Fernandez-Gines et al., 2005). Preparations of cellulose are generally produced from wheat, rice, soybeans, citrus and bamboo. Pectin is extracted from citrus peels and apple pomace. Alginates are anionic polysaccharides isolated from marine algae (e.g. brown algae) or some bacteria. All of these are used in the preparation of meat products.

Oat products are of particular interest for many reasons. To start with, they tend to cost less than meat. In addition, they contain both SDF and IDF (Gramza-Michałowska et al., 2018). Oat fibers also have good water-absorption capacity and, as a result, they are often used in the production of emulsion-type products such as sausages, pâtés, as well as in minced meat products (like burgers). Finally, they enhance the flavor and texture of some meat products, like minced meat and pork sausages (García et al., 2002). It follows that oat flour (Serdaroglu, 2006), oat bran (Talukder & Sharma, 2010) and different preparations of oat fibers are used for the enrichment of an array of meat products.

Fruits are also an important source of dietary fiber. This source can also be cost effective because fruit fibers can be obtained as byproducts of the production of juices and other plant products. These fibers can be used alone or in combination with cereal fibers, in the formulation of meat products. Dietary fibers present in the skin of the fruit are considered functional ingredients in the formulation of meat products due to their water-holding capacity and low cooking loss (García et al., 2002). In this category, watermelon rind powder (WRP) is a rich source of dietary fibers and bioactive compounds that could be used in the development of functional foods. The high total dietary fiber content in the WRP indicates promises for food product enrichment applications to produce high-fiber, value-added, healthy foods (Naknaen et al., 2016).

Other interesting sources of dietary fibers are also chitin and chitosan. The chitin (polymer of β-(1,4)-linked 2-acetamido-2-deoxy-D-glucopyranose) is found mainly in the animal kingdom, it is structurally similar to cellulose (Kardas et al., 2012). Chitin is available from the shells of marine crustaceans such as crabs and shrimps; shells and skeletons of mollusks, krill, and insects as well as the cell walls of fungi (Kurita, 2006; Kardas et al., 2012; Cheung, 2013). Chitosan is a linear polysaccharide obtained by extensive, although not total, deacetylation of chitin. Chitin and chitosan are mainly composed of the random association of two kinds of β-1,4 linked structural units: 2-amino-2-deoxy-D-glucose and N-acetyl-2-amino-2-deoxy-D-glucose. Chitin and chitosan impose stability on food emulsions. The addition of chitin and chitosan to diets as a source of fibers has been deemed completely safe.

Dietary fibers are also found in the rhizomes of plants. Their high content in the lotus rhizome, chory root, Jerusalem artichoke is well known (Tomaschunas et al., 2013; Afoakwah et al., 2015; Ham et al., 2017).

Functional and technological effects of dietary fibers used in meat products

Dietary fibers have helpful functional properties which can enhance the quality and sensory characteristics of meat products. These functional properties depend on the types of dietary fiber incorporated to products. The most important functional properties of dietary fibers used in meat products are water-holding and fat-binding capacity, viscosity, gel-forming ability and emulsification properties (Kim & Paik, 2012). The water-holding capacity of dietary fibers is dependent on the structure, the chemical composition (Chau, 2003) and the relative proportions of different types of fibers. The addition of fibers to meat products can cause the following technological effects:

1) increase the moisture-retaining capacity of minced products,
2) improve the stability of emulsions,
3) substitute fat, reduce fat content,
4) increase the yield of the product,
5) improve the texture of meat products,

6) retain the shape of the product after heat treatment and

7) Stabilizes fats and proteins, which leads to increased storage stability.

When formulating meat products, the type of dietary fiber, chemical organization of the additive, and consumer properties of the enriched meat product must be taken into account. Different types of additions associated functional properties and concomitant technological effects are summarized in Table 1.

Applications of different additives in the technology of meat products

Most scientific analytical reviews of the applications of dietary fibers are based on the source of dietary fibers (cereals, vegetables, fruit, etc.). However, such a classification does not take into account how the dietary fiber additives were derived. Additives processing influences chemical composition. Thus, the impact of these additives on the properties of the product can also be different. For example, oat flour, oat bran and a purified preparation of dietary fiber from oat can present significant differences in the concentration of dietary fiber and other nutrients. Accordingly, the dosage of these additives, as well as how the additives were derived can influence the properties of the product. Consequently, the applications of different additives in the technology of meat products were reviewed for the three groups of sources of derived dietary fibers listed below:

1) raw natural materials (vegetables, fruits, grains, flour, etc.),

2) secondary products of food processing (soy okara, bran, etc.), and

3) preparations of dietary fibers (wheat fiber 'Vitacel' and 'Jelucel'; soy fiber 'Protocol', citrus fiber 'Citri-Fi', potato fiber 'Potex' and 'Lyckery', etc.).

Applications for natural raw materials

Flours are included in this category. Flours are obtained from various natural raw materials. The effect of cereal and legume flour (wheat, barley, oat, rye, rice, corn, soy, chickpea and yellow lentil flour) on the physical, chemical, and sensory properties of beef patties has been determined. Cereal and legume flour increased yield, moisture, and fat retention and limits diameter reduction values. Oat flour increased moisture retention, texture, flavor and overall acceptability values of the cooked beef patties. Enriching minced meat with oat flour was found to increase fat and moisture retention but significantly change the cooking properties of patties. It, however, did not negatively affect organoleptic properties. This addition has also economic repercussions as it increases the profitability when selling burgers (Serdaroglu, 2006). Among the legume flours, chickpea flour had higher performance on the sensorial properties of beef patties (Kurt & Kilinççeker, 2012). The addition of chia flour as chicken skin substitute (15%) allowed to produce chicken nuggets with 'high fiber content' (Barrosa et al., 2018). Others have noted that the inclusion of 10% chia flour and olive oil in sausages allowed to increase the total amount of dietary fiber (98% IDF) (Pintado et al., 2016).

Vegetable fibers can be an attractive option to enrich certain meat products. These dietary fibers can be used as fat substitute and they tend to be used as additives to enhance the texture (juiciness, and tenderness) of certain types of meat products. Despite the fact that vegetables and fruits are a good source of dietary fiber, using them in raw form for enrichment of meat products is inefficient. This is because they contain a large amount of moisture, which can adversely affect the functional and technological parameters. In this case, the quantity of introduced dietary fiber has to be kept to a very small proportion. Alternatively, a larger portion of dried fruit and vegetables can be used.

Table 1. Dietary fibers and their technological properties in meat products

Fiber sources	Dietary fiber components	Functional properties	Technological effect in the meat product	Reference
Cereal grains and bran: wheat, ray, rice. By-products: hulls, husk.	Cellulose, hemicellulose	Water-holding and fat-holding capacity	Regulate the moisture content in the meat products and crystallization during freezing increase cooking yield and firmness; substitute fat in chicken meatballs and beef patties	Talukder & Sharma, 2010; Gibis et al. 2015; Hu & Yu, 2015
Fruits and vegetables. By-products: seeds of berries and fruits; apple, pear, tomato pomace; citrus peel	Cellulose, hemicelluose, pectin	Water-holding capacity, viscosity, gel-forming ability due to the high content of polyphenols, it exhibits antioxidant properties	Modify moisture, texture and color brightness of meat products. Improve emulsion stability and cooking yield, increase shelf-life, prevent lipid oxidation of chicken product	Turksoy & Ozkaya, 2011; Cava et al., 2012
Oats, barley grains, bran and flour	Beta-glucan, cellulose, hemicellulose	Viscosity, Water-holding and Fat-holding capacity	Decrease cooking losses and reduce fat content improve the flavor, texture, and palatability of beef and pork patties, sausages, and meatballs	Yilmaz & Daglioglu, 2003; Serdaroglu, 2006; Choi et al., 2011; Schmiele et al., 2015
Legumes: soybeans, beans, peas flour	Resistant starch, cellulose, hemicellulose	Water-holding capacity, Gel-forming ability	Reduce fat content, increase cooking yield and protein content. Improve emulsion stability, minimize the production cost of bologna sausage and chicken nuggets	Serdaroglu, 2006; Pietrasik & Janz, 2010
Chicory root, Jerusalem artichoke	Inulin, fructooligosaccharides, cellulose, hemicellulose	Water-holding capacity, gel-forming ability	Substitute fat in low-fat meat products. Promote the development of acceptable color as well as textural and sensory properties of meat products	Sun et al., 2010; Tomaschunas et al., 2013; Afoakwah et al., 2015

Table 1 (continued)

Gum guar, gum arabic, algae, agar, alginates	Gums, carageenans, alginates	Viscosity, water-holding capacity, fat-binding capacity	Replace some portion of fat in meat products. Provide stability of emulsion, and gel texture improve cooking yield, texture and water retention in the sausages and frankfurters improve cooking characteristics and decrease mass transfer and diameter reduction, provide high yield, improves the thickness of products extend the shelf-life of minced pork patties	Beriain et al., 2011; Moroney et al., 2013
Fungi and shellfish, shells of marine crustaceans	Chitin/chitosan	Gel-forming ability, high viscosity, water-holding capacity.	Stabilize the structure of meat products that leads to minimized shrinkage and improved product density improve stability of the meat emulsion	Cheung, 2013

Aloe vera is one of the interesting sources of natural dietary fiber that can be used in the technology of meat products. The results of studies on beef burgers with added Aloe vera, as well as goat meat nuggets with fresh Aloe vera gel, shown that it could be used to improve the quality of meat products. The authors noted 2.5% of Aloe vera, lead to an improved cooking yield of goat meat nuggets (Soltanizadeh & Ghiasi-Esfahani, 2015; Rajkumar et al., 2016).

The interesting source of dietary fiber is jabuticaba skin flour, obtained from jabuticaba fruit planting in Brazil. Alves et al. (2017) determined that the restructured hams with addition of 0.5% jabuticaba skin flour had virtually no changes in the physicochemical properties, except for the increase of fiber, phenolic compounds and hardness and reduced brightness.

Applications for secondary food processing additives

Bran is an example of secondary processing additive. As a source of dietary fibers in chicken patties, Talukder & Sharma (2010) found that oat bran contains more SDF than wheat bran. They also found that IDF were higher in wheat bran. The addition of bran resulted in an increase in water holding capacity and emulsion stability, as well as a significant increase in yield. The authors recommended the introduction of 10% oat and 15% wheat bran in chicken patties (Talukder & Sharma, 2010). In the studies of Choi et al. (2015), fat was partially replaced with rice bran fiber in sausages. The authors have measured the chemical, textural and sensory properties of these lower fat sausages. It was determined that the addition of rice bran fibers (2%) improved the taste while not significantly affecting textural attributes and it allowed to reduce the fat content by 12 to 30%. In Yılmaz studies (2004) rye bran was used in various amounts (between 5 and 20%) to replace fat in meatballs. The product saw an increase in its nutritional value and a decrease in its total content of trans-fatty acids. Thus, the authors concluded that rye bran can be used as a source of dietary fiber in meat products.

The processing of large quantities of vegetables and fruits generally produces by-products that are rich in dietary fibers. This wide spread and low cost raw material can be used as dietary fibers by the industry (Seo & Kyung, 2015). By-products of citrus, such as lemon albedo and orange fiber powder was added in various concentrations to cooked and dried sausages (Fernández-López et al., 2004). The authors determined that the addition of lemon albedo in an amount of 2.5% to 7.5% did not worse the organoleptic properties of sausages.

Okara is a by-product of the soy and tofu industries (Turhan et al., 2009). It is used in the production of beef patties in raw (Turhan et al., 2007) and in dried form (Turhan et al., 2009). The authors recommend adding no more than 7.5% of raw okara and not more than 22.5% of dry okara (Turhan et al., 2007; Turhan et al., 2009) in beef patties.

Applications of preparations of dietary fiber additives

Oat, rice and rye fibers are used by the food industry to enrich certain types of meat products. These types of dietary fibers tend to provide good water absorption capacity, they can enhance taste and they can offer an economical advantage as they are less costly than meat.

High absorption or bleached oats fibers have been added to determine their effects on quality characteristics of light bologna and fat-free frankfurters (Steenblock et al., 2001). The results showed that the addition of both types of oat fibers produces higher yields but, in the sausages, oat bran fibers produced a harder product (high shear stress) and contributed to the production of sausages containing less humidity. High absorption and bleached oats fibers appear to produce different textures depending on the product in which they are used (Steenblock et al., 2001).

Jongaroontaprangsee et al. (2007), and Nilnakara et al. (2009) have obtained fibers from the outer leaves of cabbage and Seo & Kyung (2015) produced dietary fibers from Chinese cabbage waste. From these studies, it was determined that the powder from cabbage outer leaves possessed high water-holding and swelling capacities, indicating potential for use in many food applications (Jongaroontaprangsee et al., 2007). In addition, Seo & Kyung (2015) noted that dietary fibers derived from Chinese cabbage waste have probiotic, hypoglycemic and hypolipidemic effects.

Potato, cactus pear and pineapple fibers were also tested to improve meat products. The addition of dietary fiber from dry potato pulp, Potex and enzymatically extracted non-starch polysaccharides in pâtés allowed not only to reduce the content of animal fat, but also to improve the texture of the product. Dıaz-Vela et al. (2017) used cactus pear and pineapple fibers as a source of dietary fibers in boiled sausages.

Soy fibers are used in meat products to increase yields because of their high water- and fat-holding capacities. Soy fibers are used to improve the structure of the sausage (Cofrades et al., 2008). In minced meat, the introduction of a soy fiber ‘Protocol’ allows to condense the structure of the finished product by creating a ‘three-dimensional skeleton’. This is particularly useful when low grade raw materials are used.

Inulin is a SDF which can be used as a fat substitute in meat products. For example, Mendoza et al. (2001) conducted a study using dry fermented sausages with a fat content close to 50 and 25% of the original amount by adding 7.5 and 12.5% of inulin, respectively. The results showed that the dry fermented sausages obtained had technological properties similar to conventional sausages, while they had a softer texture and tenderness, springiness and adhesiveness. The low-calorie dry-fermented sausages are currently available on the market and they contain approximately 10% inulin (Mendoza et al., 2001).

Pea fibers (obtained from the inner cell wall of yellow peas) contain about 48% fat, 44% starch, and 7% protein. This additive was added to beef patties, in a dry form. The aim was to lower fat by 10% to 14%. The recipe lead to an improvement of the tenderness and increased the yield with no detriment on juiciness and flavor (Anderson & Berry, 2000).

Lopez-Marcos et al (2015) obtained dietary fibers from different agro-industrial co-products. These included lemon dietary fibers, grapefruit dietary fibers, pomegranate dietary fiber, lemon albedo dietary fiber, and tiger nut fiber. Studies conducted using the obtained products showed that the emulsifying capacity and emulsion stability was generally high. On that basis, the authors suggest the possibility of using such types of dietary fibers in products that require emulsifiers and have a long shelf life (as they require long-term stability). The authors determined that lemon dietary fibers and grapefruit dietary fibers samples, with the highest soluble dietary fiber content, showed higher water holding capacity values then tiger nut fiber samples (with the lowest soluble dietary fiber content). In addition, the highest fat / oil binding values were obtained for lemon dietary fibers and lemon albedo dietary fiber samples, suggesting that the higher the ratio of the soluble dietary fiber / insoluble dietary fiber, the higher the fat / oil binding capacity. The authors also indicated that these fibers have the potential to reduce the adsorption of cholesterol (Lopez-Marcos et al., 2015).

Garcia and others (2002) conducted studies on reduced-fat dry-fermented sausages prepared with the addition of 1.5 and 3% cereal (wheat and oat) and fruit (peach, apple, and orange) fibers (García et al., 2002). The authors noted that the best sensory characteristics were obtained in sausages with the introduction of 1.5% fiber, especially orange fibers. In this case, it was found that a higher amount of fibers worsened the texture (Fernandez-Gines et al., 2005).

The sections above provided examples of how materials containing fibers can affect physical properties of meat products. Data reported in the literature on the effect of dietary fibers in various meat products with an indication of the established optimal dosages are summarized in Table 2.

Using combinations of dietary fibers in the formulation of meat products

Recently, a number of studies have been conducted on the usage of combinations of various types of dietary fiber in meat products. For example, Petridis et al. (2014) studied the cumulative synergistic effects of citrus fiber, rice bran and collagen on the texture and selected sensory characteristics of frankfurter-type sausages. An emulsion from pork skin has been used as a source of collagen. The most acceptable formulations were with 13% of collagen addition, 1.5% of citrus fiber and 0.5% of rice bran or 13% of collagen addition with 2% of citrus fiber. The authors mentioned that, for both formulations low fattiness and brittleness were achieved while a moderate elasticity was obtained. Using both formulations, sausages were adequately hard and cohesive and differed solely in color intensity (moderate vs light reddish) (Petridis et al., 2014).

Kılınççeker & Kurt (2018) studied the effects of inulin, carrot, and cellulose fiber additions on chicken meatballs. The authors noted that the use of fibers in meatballs can boost product quality and improve color properties (L, a, b values). Cellulose and carrot fibers augmented the yield and moisture absorption values while preventing diameter reduction of the fried samples.

Combinations of different types of fibers additives as part of meat formulations are currently being studied. It follows that we will be seeing more of these types of products in the market place.

Various non-traditional dietary fibers are used in other food products. Their high functional and technological potential show great promise for their integration in meat product formulations.

CONCLUSION

Although existing definitions of dietary fibers have common concepts and elements, no consensus has been reached to date. This may be due to the diversity of dietary fibers, the multiplicity of forms in which they may be available and, therefore, the complexity of possible physical and chemical interactions that may be taking place within the gastro-intestinal tract. The modern classification systems for dietary fibers reflect this. It is wide and diverse and can be based, for example, on origin, structure, solubility or physiological effect. Numerous positive physiological effects of the use of dietary fibers have been documented. These include curative and preventive effects for diseases or conditions such as obesity, certain types of cancers, cardiovascular diseases, diabetes, and constipation. Research on various types of dietary fibers continues to contribute new data on the health benefit of dietary fibers.

Table 2. Effects of dosages of dietary fibers on the properties of various meat products

Groups	Source of fibers	Meat product	% Recommended	Determined effect	References
Natural product	Barley flour	Sausages	3.9 to 6.9*	Increase water absorption index and viscosities, reduce fat content	Choi et al., 2011
	Chia flour	Chicken nuggets	10	Decrease the moisture, saturated fatty acids and monounsaturated fatty acids contents; lower the acceptability of the meat product	Barrosa et al., 2018
		Sausages	10	Increase the total amount of dietary fiber	Pintado et al., 2016
	Oat flour	Beef patties	4.0	Increase the juiciness scores, no effect on other sensory properties, improve the cooking characteristics	Serdaroglu, 2006
			5.0	Increase moisture retention, odor, texture, flavor and overall acceptability values	Kurt & Kilinççeker, 2012
	Legume flour	Beef patties	5.0	Increase yield, moisture, and fat retention and decrease diameter reduction values	
	Aloe vera gel	Goat meat nuggets	up to 2.5	Decrease ph value and protein content; reduce the lipid oxidation and microbial growth during storage	Rajkumar et al., 2016
	Jabuticaba skin flour	Restructured hams	0.5	Higher contents of phenolic compounds; greater weight loss; a darker shade; texture profile with smaller parameters of stiffness, cohesiveness, adhesiveness, flexibility and chewiness	Alves et al., 2017
Secondary food processing	Rye bran	Meatballs	20	Reduce total trans fatty acid, increase ratio of total unsaturated fatty acids to total saturated fatty acids, reduce weight losses, improve nutritional value, health benefits and color	Yilmaz, 2004
	Chickpea hull flour	Chicken nuggets	5	Decrease in total cholesterol and glycolipid content, reduce sensory scores	Verma et al., 2012
	Rice bran	Frankfurters	2	Reduce the moisture, ash, carbohydrate, energy value, cooking loss, and total expressible fluid, improve flavor and overall acceptability	Choi et al., 2015
	Wheat bran Oat bran	Chicken meat patties	15 10	Increase the water holding capacity and emulsion stability; increase in cooking yield, firmness, reduction in sensory attributes, moisture, protein, fat and cholesterol content.	Talukder & Sharma, 2010
	Okara powder	Beef patties	up to 7.5	Reduce the cholesterol content, increased the energy values; improve whc, cook loss and shrinkage, increase the ph, lightness and yellowness values	Turhan et al., 2009

Table 2 (continued)

Preparations of dietary fibers	Oat fiber	Light bologna, frankfurters	3	Increase yields and hardness and contribute to lighter red color	Steenblock et al., 2001
	Fruit (orange) fiber	Dry fermented sausages	1.5	Reduce energy value; reduce fat without loss of sensory quality	García et al., 2002
	Inulin	Emulsion type sausages	6	Reduce fat, energy content and color measurement; sensory evaluation comparable to the traditional product	Berizi et al., 2017
		Fermented sausages	10	Reduce calorie, improve softness, tenderness, springiness, and adhesiveness	Mendoza et al., 2001
	Bacterial cellulose (Nata)	Chinese-style meatball	10	Acceptable textural and sensory qualities, decrease in cohesiveness value	Lin & Lin, 2004
	Soy fiber	Bologna sausages	2.5	Improve fat and water binding properties, reduce fat, decrease textural properties and increase weight loss	Cofrades et al., 2008
	Guar gum, xanthan gum, gum Arabic	Fried beef patties	1.5	Effect on yield and diameter reduction; increase the moisture retention; gum arabic increase lightness and yellowness values	Kilincceker & Yilmaz, 2016
	Microcrystal-line cellulose	Beef patties	2.0	Decrease moisture loss; improve the texture in the sensory evaluation had more juiciness than the control and had a fat-like mouthfeel	Gibis et al., 2015
Combined	Citrus fiber rice bran pork skin	Frankfurter sausages	1.5 0.5 13.0	Positive effect on the acceptability of the samples. Adequately hard and cohesive, differing solely in the intensity of color (moderately and low reddish)	Petridis et al., 2014
	Inulin, carrot fibres cellulose fibres	Chicken meatballs	3 9 6 or 9	Improve color properties (lightness, yellowness values), improve the technological properties	Kılınççeker & Kurt, 2018

*for different fraction.

In recent years, more and more sources of dietary fibers have been discovered and tested. In this review, the information relevant to meat products was gathered. Traditional sources of dietary fibers added to meat products include cereals, vegetables and fruits. Non-traditional sources of dietary fibers include fungi, and secondary products of animal processing. Fibers can be used in raw and processed forms. Formulations now comprise combinations of dietary fibers.

All classes of dietary fibers can be used in the fabrication of healthy meat products (usually with lower fat content). In most cases, formulations can be adjusted such that additional sensory and functional-technological indicators (moisture binding, emulsifying ability, palatability, color) benefits can be offered. In some cases, the taste can also be improved.

Consumers recognize that their health can be improved through diet and this review showed that, as results, there is a trend for an increasing use of products containing dietary fibers amongst consumers. In fact, at the moment, the use of dietary fiber in the production of meat products is becoming widespread. It follows that manufacturers are looking to improve the functional and technological properties of their products. Meat manufacturers are also interested in increasing the yield of their products. With both consumers and manufacturers engaged, the use of dietary fiber will no doubt contribute to improving the health of the population. It will also contribute to the enhancement of functional properties of many meat products while promoting the usage of available raw materials from other food industry sectors.

ACKNOWLEDGMENTS. The work was supported by Act 211 Government of the Russian Federation, contract No. 02.A03.21.0011. The authors thank the reviewers for their valuable comments during the preparation of this article.

Conflict of Interest.
The authors declare no conflicts of interest.

REFERENCES

Afoakwah, N.A., Dong, Y., Zhao, Y.S., Xiong, Z.Y., Owusu, J., Wang, Y. & Zhang, J.Y. 2015. Characterization of Jerusalem artichoke (Helianthus tuberosus L.) powder and its application in emulsion-type sausage. *LWT-Food Science and Technology* **64**(1), 74–81.

Alves, A.P.C., Marques, T.R., Carvalho, T.C.L., Pinheiro, A.C.M., Ramos, E.M. & Corrêa, A.D. 2017. Elaboration and acceptability of restructured hams added with jabuticaba skin. *Food Science and Technology*, *Campinas* **37**(2), 232–238.

Anderson, T. & Berry, W. 2000. Sensory Shear and cooking properties of lower fat beef patties made with inner pea fiber. *Journal of Food Science* **65**(5), 805–810.

Barrosa, J.C., Munekataa, P.E., Pires, M., Rodrigues, I., Andaloussi, O.S., Rodrigues, C.E.C. & Trindade, M.A. 2018. Omega-3- and fibre-enriched chicken nuggets by replacement of chicken skin with chia (Salvia hispanica L.) flour. *LWT – Food Science and Technology* **90**, 283–289.

Beriain, M.J., Gomez, I., Petri, E., Insausti, K. & Sarries, M.V. 2011. The effects of olive oil emulsified alginate on the physico-chemical, sensory, microbial, and fatty acid profiles of low-salt, inulin-enriched sausages. *Meat Science* **88**, 189–197.

Berizi, E., Shekarforoush, S.S., Mohammadinezhad, S., Hosseinzadeh, S. & Farahnaki, A. 2017. The use of inulin as fat replacer and its effect on texture and sensory properties of emulsion type sausages. *Iran Journal of Veterinary Research* **18**(4), 253–257.

Bis-Souza, C.V., Henck, J.M.M. & Barretto, A.C.S. 2018. Performance of low-fat beef burger with added soluble and insoluble dietary fibers. *Food Science and Technology, Campinas* **38**(3), 522–529.

Cava, R., Ladero, L., Cantero, V. & Ramirez, M.R. 2012. Assessment of different dietary fibers (tomato fiber, beet root fiber, and inulin) for the manufacture of chopped cooked chicken products. *Journal of Food Science* **77**, 346–352.

Chau, C.F. & Huang, Y.L. 2003. Comparison of the chemical composition and physicochemical properties of different fibers prepared from the peel of Citrus sinensis L. Cv. Liucheng. *Journal of Agricultural and Food Chemistry* **51**, 2615–2618.

Cheung, K. 2013. Mini-review on edible mushrooms as source of dietary fiber: preparation and health benefits. *Food Science and Human Wellness* **2**(3), 162–166.

Choi, J.W., Kim, S.H. & Mun, S. 2011. Optimizing the replacement of pork fat with fractionated barley flour paste in reduced-fat sausage. *Food Science and Biotechnology* **20**, 687–694.

Choi, Y., Kim, L., Hwang, K., Song, D., Jeong, T., Kim, Y., Jeon, K. & Kim, C. 2015. Effects of fat levels and rice bran fiber on the chemical, textural, and sensory properties of frankfurters. *Journal of Food Science and Biotechnology* **24**(2), 489–495.

Cofrades, S., Guerra, M., Carballo, J., Fernández-Martín, F. & Jiménez Colmenero, F. 2008. Plasma protein and soy fiber content effect on bologna properties as influenced by fat level. *Journal of Food Science* **65**(2), 281–287.

Dıaz-Vela, J., Totosaus, A., Escalona-Buendıa, H.B. & Perez-Chabela, M.L. 2017. Influence of the fiber from agro-industrial co-products as functional food ingredient on the acceptance, neophobia and sensory characteristics of cooked sausages. *Journal of Food Science and Technology* **54**(2), 379–385.

Fernandez-Gines, M., Fernandez-Lopez, J., Sayas-Barbera, E. & Pérez-Alvarez, J.A. 2005. Meat products as functional food: A review. *Journal of Food Science* **70**, 37–43.

Fernández-López, J., Fernández-Ginés, J.M., Alerón-Carbonell, L., Sayas-Barberá, E., Sendra, E. & Pérez-Álvarez, J.A. 2004. Application of functional citrus by-products to meat products. *Trends Food Science and Technology* **15**, 176–185.

Fuller, S., Beck, E., Salman, H. & Tapsell, L. 2016. New Horizons for the Study of Dietary Fiber and Health: A Review. *Plant Foods for Human Nutrition* **71**, 1–12.

García, L., Domínguez, R., Galvez, D., Casas, C. & Selgas, D. 2002. Utilization of cereal and fruit fibres in low fat dry fermented sausages. *Meat Science* **60**, 227–232.

Gibis, M., Schuh, V. & Weiss, J. 2015. Effects of carboxymethyl cellulose (CMC) and microcrystalline cellulose (MCC) as fat replacers on the microstructure and sensory characteristics of fried beef patties. *Food Hydrocolloids* **45**(2), 236–246.

Gramza-Michałowska, A., Kmiecik, D., Kobus-Cisowska, J., Żywica, A., Dziedzic, K. & Brzozowska, A. 2018. Phytonutrients in Oat (Avena sativa L.) Drink: Effect of Plant Extract on Antiradical Capacity, Nutritional Value and Sensory Characteristics. *Polish Journal of Food and Nutrition Sciences* **68**(1), 63–71.

Ham, Y.-K., Hwang, K.-E., Song, D.-H., Kim, Y.-J., Shin, D.-J., Kim, K.-I., Lee, H.-J., Kim, N.-R. & Kim, C.-J. 2017. Lotus (Nelumbo nucifera) Rhizome as an Antioxidant Dietary Fiber in Cooked Sausage: Effects on Physicochemical and Sensory Characteristics. *Korean Journal of Food Science of Animal Resources* **37**(2), 219–227.

Hipsley, H. 1953. Dietary “Fibre” and Pregnancy Toxaemia. *British Medical Journal* **2**(4833), 420–422.

Hu, G.H. & Yu, W.J. 2015. Effect of hemicellulose from rice bran on low fat meatballs chemical and functional properties. *Food Chemistry* **186**, 239–243.

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

Jongaroontaprangsee, S., Tritrong, W., Chokanaporn, W., Methacanon, P., Devahastin, S. & Chiewchan, N. 2007. Effects of drying temperature and particle size on hydration properties of dietary fiber powder from lime and cabbage by products. *International Journal of Food Properties* **10**, 887–897.

Kardas, I., Struszczyk, M.H., Kucharska, M., van den Broek, L.A.M., van Dam, J.E.G. & Ciechan´ska, D. 2012. *Chitin and Chitosan as Functional Biopolymers for Industrial Applications*. In P. Navard (Ed.). The European Polysaccharide Network of Excellence (EPNOE), Springer-Verlag Wien, pp. 329–373.

Kılınççeker, O. & Kurt, Ş. 2018. Effects of inulin, carrot and cellulose fibres on the properties of raw and fried chicken meatballs. *South African Journal of Animal Science* **48**(1), 39–48.

Kilincceker, O. & Yilmaz, M.T. 2016. Effects of different gums on the some properties of fried beef patties. *Carpathian Journal of Food Science and Technology* **8**(2), 63–70.

Kim, H.J. & Paik, H.D. 2012. Functionality and Application of Dietary Fiber in Meat Products. *Korean Journal for Food Science of Animal Resources* **32**(6), 695–705.

Kurita, K. 2006. Chitin and Chitosan: Functional Biopolymers from Marine Crustaceans. *Marine Biotechnology* **8**, 203–226.

Kurt, Ş. & Kilinççeker, O. 2012. The Effects of Cereal and Legume Flours on the Quality Characteristics of Beef Patties. *Kafkas Universitesi Veteriner Fakultesi Dergisi* **18**(5), 725–730.

Lin, K.W. & Lin, H.Y. 2004. Quality characteristics of Chinese-style meatball containing bacterial cellulose (Nata). *Journal of Food Science* **69**, 107–111.

López-Marcos, M.C., Bailina, C., Viuda-Martos, M., Pérez-Alvarez, J.A. & Fernández-López, J. 2015. Properties of Dietary Fibers from Agroindustrial Co-products as Source for Fiber-Enriched Foods. *Food and Bioprocess Technology* **8**, 2400–2408.

Mallika, E., Prabhakar, K. & Reddy, M. 2009. Low Fat Meat Products - An Overview. *Veterinary world* **2**(9), 364–366.

Mendoza, E., García, L., Casas, C. & Selgas, D. 2001. Inulin as fat substitute in low fat, dry fermented sausages. *Meat Science* **57**, 387–393.

Moroney, N.C., O'Grady, M.N., O'Doherty, J.V. & Kerry, J.P. 2013. Effect of a brown seaweed (Laminariadigitata) extract containing laminarin and fucoidan on the quality and shelf-life of fresh and cooked minced pork patties. *Meat Science* **94**(3), 304–311.

Naknaen, P., Itthisoponkul, T., Sondee, A. & Angsombat, N. 2016. Utilization of Watermelon Rind Waste as a Potential Source of Dietary Fiber to Improve Health Promoting Properties and Reduce Glycemic Index for Cookie Making. *Food Science and Biotechnology* **25**(2), 415–424.

Nilnakara, S., Chiewchan, N. & Devahastin, S. 2009. Production of antioxidant dietary fibre powder from cabbage outer leaves. *Food and Bioproducts Processing* **87**, 301–307.

Petridis, D., Raizi, P. & Ritzoulis, Ch. 2014. Influence of Citrus Fiber, Rice Bran and Collagen on the Texture and Organoleptic Properties of Low-Fat Frankfurters. *Journal of Food Processing & Preservation* **38**(4), 1759–1813.

Pietrasik, Z. & Janz, J.A.M. 2010. Utilization of pea flour, starch-rich and fiber-rich fractions in low fat bologna. *Food Research International* **43**, 602–608.

Pintado, T., Herrero, M., Jimenez, F. & Ruiz, C. 2016. Strategies for incorporation of chia (Saliva hispanica L.) in frankfurters as a health-promoting ingredient. *Meat Science* **114**, 75–84.

Rajkumar, V., Arun, K.V., Patra, G., Pradhan, S., Biswas, S., Chauhan, P. & Arun, K.D. 2016. Quality and Acceptability of Meat Nuggets with Fresh Aloe vera Gel. Asian Australas. *Journal of Animal Science* **29**(5), 702–708.

Schmiele, M., Mascarenhas, M., Barretto, A.C.D. & Pollonio, M.A.R. 2015. Dietary fiber as fat substitute in emulsified and cooked meat model system. *LWT-Food Science and Technology* **61**(1), 105–111.

Seo, P. & Kyung, Y. 2015. Enzymatic Production of Soluble Dietary Fiber from the Cellulose Fraction of Chinese Cabbage Waste and Potential Use as a Functional Food Source. *Food Science and Biotechnology* **24**(2), 529–535.

Serdaroglu, M. 2006. The characteristics of beef patties containing different levels of fat and oat flour. *Journal of Food Science Technology* **41**, 147–153.

Soltanizadeh, N. & Ghiasi-Esfahani, H. 2015. Qualitative improvement of low meat beef burger using Aloe vera. *Meat Science* **99**(1), 75–80.

Steenblock, L., Sebranek, G., Olson, G. & Love, A. 2001. The effects of oat fiber on the properties of light bologna and fat-free frankfurters. *Journal of Food Science* **66**(9), 1409–1415.

Sun, C.Y., Wang, J. & Zhang, K.S. 2010. Process research on inulin as the fat substitute. *Food Fermentation Technology* **46**, 56–60.

Sze, N., Sathyasurya, R. & Wan, N. 2017. Incorporation of dietary fibre-rich oyster mushroom (Pleurotussajor-caju) powder improves postprandial glycaemic response by interfering with starch granule structure and starch digestibility of biscuit. *Food Chemistry* **227**, 358–368.

Talukder, S. & Sharma, D. 2010. Development of dietary fiber rich chicken meat patties using wheat and oat bran. *Food Science and Technology* **47**(2), 224–229.

Tomaschunas, M., Zorb, R., Fischer, J., Kohn, E., Hinrichs, J. & Busch-Stockfisch, M. 2013. Changes in sensory properties and consumer acceptance of reduced fat pork Lyon-style and liver sausages containing inulin and citrus fiber as fat replacers. *Meat Science* **95**(3), 629–640.

Trowell, H., Burkitt, D. & Heaton, K. 1985. Definition of dietary fibre and fibredepleted food. In Trowell H., Burkitt D., Heaton K. (Eds.), *Dietary fibre, fibredepleted foods and diseases*. Academic Press New York, pp. 21–30.

Turhan, S., Temiz, H. & Sagir, I. 2009. Characteristics of beef patties using okara powder. *Journal of Muscle Foods* **20**, 89–100.

Turhan, S., Temiz, H. & Sagir, I. 2007. Utilization of wet okara in low-fat beef patties. *Journal of Muscle Foods* **18**, 226–235.

Turksoy, S. & Ozkaya, B. 2011. Pumpkin and carrot pomace powders as a source of dietary fiber and their effects on the mixing properties of wheat flour dough and cookie quality. *Food Science and Technology Research* **17**(6), 545–553.

Verma, A.K., Banerjee, R. & Sharma, B.D. 2012. Quality of Low Fat Chicken Nuggets: Effect of Sodium Chloride Replacement and Added Chickpea (Cicer arietinum L.) Hull Flour. *Asian-Australian Journal of Animal Science* **25**(2), 291–298.

Yilmaz, I. 2004. Effects of rye bran addition on fatty acid composition and quality characteristics of low-fat meatballs. *Meat Science* **67**, 245–249.

Yilmaz, I. & Daglioglu, O. 2003. The effect of replacing fat with oat bran on fatty acid composition and physicochemical properties of meatballs. *Meat Science* **65**, 819–823.

Zhang, W., Xiao, S., Samaraweera, H., Lee, E.J. & Ahn, D.U. 2010. In Special Issue: 56th International Congress of Meat Science and Technology (56th ICoMST), Korea. *Meat Science* **86**(1), 15–31.

Zielinski, G. & Rozema, B. 2013. Review of fiber methods and applicability to fortified foods and supplements: choosing the correct method and interpreting results. *Analytical and Bioanalytical Chemistry* **405**, 4359–4372.