

*Review Article*

## **Fibre-based functional meat products**

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### **Abstract**

Epidemiological studies have demonstrated a relationship between a diet containing an excess of energy-dense food rich in fats and sugar and the emergence of a range of chronic diseases, including colon cancer, obesity, cardiovascular diseases and several other disorders [12, 49, 9, 77, 13, 14]. As the presence of fibre in food produces a diminution in their caloric content, thus, an increase in the level of dietary fibre in the daily diet has been recommended [32, 47, 13]. Studies have proven that dietary fibres have the potential to reduce blood low density lipoprotein cholesterol [18], risk of diabetes mellitus type 2 [94], coronary heart disease [7], blood pressure [87], obesity [56] and colorectal cancer [79]. Fibre is suitable for addition to meat products and has previously been used in cooked meat products to increase the cooking yield due to its water-binding and fat-binding properties and to improve texture [23, 13, 15]. Fibre from various types of sources like vegetables, legumes, cereal byproducts, fruit, etc. have been studied alone or combined with other ingredients for formulations of reduced-fat-high-fibre meat products, largely ground and restructured products [28, 57] and meat emulsions [22, 21, 40, 53, 55, 15]. This paper reviews and discusses some of the findings published in recent years regarding fibre-based functional meat products.

**Keywords:** Functional food, meat, meat products, fibre, health benefits, India.

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### **Introduction**

Functional food may be defined as a food that may provide health benefits beyond basic nutrition and is similar in appearance to conventional food that is intended to be consumed as part of a normal diet, but has been modified to subserve physiological roles beyond the provision of simple nutrient requirements [8]. Typically, a food marketed as functional contains added, technologically developed ingredients with a specific health benefit [66]. Although the term “functional food” has already been defined several times [75], so far there is no unitary accepted definition for this group of food [4]. In most countries there is no legislative definition of the term and drawing a border line between conventional and functional food is challenging even for nutrition and food experts [58, 66]. Food is not intended to only satisfy hunger and to provide necessary nutrients for humans, but also to prevent nutrition-related diseases and improve physical and mental well-being of the consumers [60, 74]. It

was recognized that there is a demand for these products as different demographical studies revealed that the medical service of the aging population is rather expensive [58, 60, 84]. The concept of functional food was first promoted in 1984 by Japanese scientists who studied the relationships between nutrition, sensory satisfaction, fortification and modulation of physiological systems. In 1991, the Ministry of Health introduced rules for approval of a specific health-related food category called FOSHU (Food for Specified Health Uses) which included the establishment of specific health claims for this type of food [19, 60, 74]. The amount of intake and form of the functional food should be as it is normally expected for dietary purposes. Therefore, it could not be in the form of pill or capsule just as normal food form [29]. On the contrary to this latter statement, since 2001 FOSHU products in Japan can also take the form of capsules and tablets, although a great majority of products are still in more conventional forms [67]. European legislation however, does not consider functional food as a specific food category, but rather as a concept [26, 85]. Functional food comprises conventional food containing naturally occurring bioactive substances (e.g. dietary fibre) or food enriched with bioactive substances (e.g., probiotics, antioxidants) or synthesized food ingredients introduced to traditional food (e.g., prebiotics).

Meat and meat products are essential in the diet of the modern world. Food of animal origin including meat is required to maintain the health of a human body [65]. Their principal components, besides water, are proteins and fats, with a substantial contribution of vitamins and minerals of a high degree of bioavailability. Meat is specifically valuable as a source of omega-3 fatty acids, vitamin B12, protein and highly bioavailable iron [11]. Meat and its derivatives may also be considered functional food to the extent that they contain numerous compounds thought to be functional. Both meat and its associated products can be modified by adding ingredients considered beneficial for health or by eliminating or reducing components that are considered harmful. In this way, a series of food products can be obtained which, without altering their base, are considered "healthy". This idea of using food for health purposes rather than for nutrition opens up a whole new field for the meat industry. In addition to traditional presentations, the industry can explore various possibilities, including the control of the composition of raw and processed materials via addition of a variety of fibre sources.

There is a growing awareness that many chronic diseases are caused by energy dense food like meat. Sadri and Mahjub [77] found a positive association between meat consumption and colorectal cancer. But the studies have shown that the consumption of fruit, legumes and vegetables, etc. impart the essential dietary fibre besides having many other health benefits mainly attributed to organic micronutrients such as carotenoids, polyphenolics, tocopherols, vitamin C and others [80, 89]. The role of dietary fibre in controlling chronic disorders like diverticulitis, bowel cancer, cardiovascular diseases, diabetes, constipation, etc. has been well documented [68, 94, 18, 7, 56, 89, 79, 87, 50, 51]. Dietary fibre can be added to meat and meat based products via many sources like vegetables, fruit, legumes, cereals, etc. in the form of extenders, fillers, binders, etc. Besides adding the important ingredient i.e. fibre to the meat products, these also improve the other characteristics of the products and increase the profit margins of the industry. Vegetables are the main ingredient of a range of meat-free dishes and convenience products such as vegetable burgers, vegetable based sausages, vegetable grills and ready meals. The attributes of vegetables include high fibre, low fat and low energy density. Particular types of vegetables can also be a good source of vitamins including vitamin C, folic acid, other B vitamins, vitamins E and K, potassium, dietary antioxidants such as carotenoids and flavonoids and a range of other potentially beneficial phytochemicals. Protein derivatives of vegetable origin have been used in meat products for technological purposes to reduce formulation costs and they have even been used for their nutritional value [45]. The use of wheat protein as a meat alternative is a relatively recent development. Wheat protein is essentially made from gluten that has been processed and extruded to resemble the texture of meat [76].

Verma, *et al* [92] studied the effect of 40% sodium chloride replacement with salt substitute blend (potassium chloride, citric acid, tartaric acid and sucrose) and incorporation of apple pulp, at the levels of 8 (Treatment I), 10 (Treatment II) and 12 (Treatment III) g/100 g of formulation, on the various quality characteristics of low fat chicken nuggets. Apple pulp addition resulted in significantly lower ( $P < 0.05$ ) emulsion stability and cooking yield and among low salt and low fat nuggets; the product with 12 g/100 g apple pulp had the highest moisture content. Incorporation of apple pulp significantly increased ( $P < 0.01$ ) dietary fibre content, redness, yellowness and chroma index of the product. Textural properties of the products significantly decreased ( $P < 0.01$ ) with substitution of common salt and addition of apple pulp. Galanakis, *et al* [38] studied the effect of a dietary fibre obtained from olive mill wastewater. A dietary fibre containing material, named as alcohol insoluble residue (AIR), was recovered from the olive mill wastewater (OMW) and was separated into different fractions (water soluble and insoluble AIR) and characterized with regard to fibre and ion content. AIR as well as water soluble fraction (WSAIR) were utilized as fat replacement in meatballs together or separately with carrot and starch and compared with regard to the total water and fat loss or oil uptake during frying of the meatballs. Results indicated that AIR could not be considered as a potential fat replacement in meatballs due to the restricted water holding ability. Nevertheless, WSAIR could be utilized together with carrot fibre as additive in low fat meatballs, since it was able to improve the cooking properties of the product, by restricting the oil uptake and thereby giving rise to meatballs with sustained reduced fat content. Taludkar and Sharma [88] developed dietary fibre rich chicken meat patties by incorporating wheat and oat bran to chicken meat at 5, 10 and 15% levels. Oat bran contained higher amount of soluble dietary fibre (SDF) and unsaturated fatty acids (USFA) than wheat bran, whereas total dietary fibre (TDF), insoluble dietary fibre (IDF) and saturated fatty acids (SFA) were higher in wheat bran. Incorporation of bran significantly increased the water holding capacity (WHC) and emulsion stability (ES). Oat bran showed better effect on WHC and ES than wheat bran. Addition of bran resulted in significant increase in cooking yield, firmness, TDF, USFA and reduction in sensory attributes, moisture, protein, fat and cholesterol content. IDF was higher in wheat bran added patties and SDF and SFA/USFA ratio in oat bran added patties. It was concluded that oat and wheat bran can be incorporated up to 10 and 15% levels, respectively, for preparation of baked and steamed chicken patties. Dzudie, *et al* [31] extended beef sausages with common bean flour using 5 levels of fat and added water (AW) (25% fat/5% AW; 20% fat/10% AW; 15% fat/15% AW; 10% fat/20% AW and 5% fat 25% AW). Decreasing in fat levels with a simultaneous increase in the amount of added water did not affect ( $P > 0.05$ ) pH and ash content, but decreased cooking yields and increased expressible moisture. The lowest  $L^*$  (lightness) values ( $p < 0.05$ ) were recorded for the 25% fat/5% AW formulation. High-fat, low-added water batter required more extrusion shear stress than low-fat, high-added water batter. Beef sausage textural characteristics were reduced by replacing added water by fat.

Nuts provide high levels of protein and also contain dietary fibre and various bioactive compounds such as plant sterols, which have cholesterol lowering properties [42, 76]. The addition of walnuts to restructured beef steak was studied by Jimenez-Colmenero, *et al* [44]. The results showed that the addition of walnuts affects the cooking properties, colour, texture and sensory attributes, making the product softer and providing it with better water-binding properties. Yilmaz [95] used rye bran as a fat substitute in the production of meatballs. Rye consumption has been reported to inhibit breast and colon tumor growth in animal models, to lower glucose response in diabetics and to lower the risk of death from coronary heart disease. The addition of rye bran to meatballs at the levels assayed (5% to 20%) 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. The author concluded that this type of fibre can be used as dietary fibre source. Steenblock, *et al* [86] added oats to determine its effect on the quality characteristics of light bologna and fat-free frankfurters. Different types of oat fibre were used; high absorption (HA) or bleached oat (BL) fibre at levels up to 3%. The results indicated that the addition of both types of oat fibre produced greater yields and a lighter red

colour. Purge was reduced with oat fibre at 3%. Product hardness increased for bologna. It has been reported that oat bran and oat fibre provide the flavour, texture and mouthfeel of fat in ground beef and pork sausages [39]. Dawkins, *et al* [27] formulated chevon (goat) meat-based patties with oat bran (15–50% w/w) and evaluated for nutrient content and physicochemical properties. Moisture, fat and protein decreased with increased oat bran. Patties containing oat bran had higher concentrations of unsaturated fatty acids and lower cholesterol. Additions of oat bran also reduced sodium and zinc. Soluble and insoluble fibre content of patties increased, while cooking loss and shear force of patties decreased with increased oat bran. Nutritional value of patties was enhanced with minimal composition and texture changes at 15 or 20% oat bran addition. Caceres, *et al* [20] studied the effect of short-chain fructooligosaccharide (FOS), a generic name for all nondigestible oligosaccharides composed mainly of fructose, on cooked sausages. The addition did not affect the pH, aw or weight losses because the presence of soluble dietary fibre (SDF) leads to a compact gel structure and therefore prevents proteins from retaining the water. 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 at 12% SDF. The hardness of the samples with SDF was lower and the overall acceptability in the sensory analysis was higher in samples with 12% SDF. Mendoza, *et al* [59] prepared low-fat, dry-fermented sausages with a fat content close to 50 and 25% of the original amount and supplemented with 7.5 and 12.5% of inulin, another SDF which can be used as a fat substitute. The results indicate that inulin impacts a softer texture and a tenderness, springiness and adhesiveness very similar to that of conventional sausages. A low-calorie product (30% of the original) can be obtained with approximately 10% inulin.

Anderson and Berry [5] studied the effects of inner pea fibre on lower-fat beef patties (10% and 14%), in which it improved tenderness and cooking yield without having negative effects on juiciness and flavour. Another important source of fibre is fruit, which can also be obtained as by-products of plant food processing. Citrus byproducts (lemon albedo and orange fibre powder) have been added, at different concentrations, to cooked and dry-cured sausages with excellent results [2, 3, 35, 36]. Fernandez-Gines, *et al* [36] added lemon albedo at different concentrations (2.5% to 10%) to cooked sausages whereas Aleson-Carbonell, *et al* [2, 3] added lemon albedo at different concentration to dry-cured sausages. The addition of lemon albedo to both sausages had healthy effects due to the presence of active biocompounds, which induced a decrease in residual nitrite levels. Sausages with 2.5% to 7.5% lemon albedo added had sensory properties similar to conventional sausages. Fernandez-Gines, *et al* [35] studied the effects of orange fibre powder at different concentrations (0.5% to 2%) on cooked sausages (bolognas). The results showed that the addition improved the nutritional value, decreased the residual nitrite level and delayed the oxidation process as determined by TBA values and the red colour. Garcia, *et al* [39] studied the effect of adding cereal and fruit fibre on the sensory properties of reduced-fat, dry-fermented sausages. The cereal (wheat and oat) and fruit (peach, apple, and orange) dietary fibres were added at 1.5% and 3% concentrations. The addition of dietary fibre from cereals and fruit at 1.5% resulted in sausages with a final fibre content, after ripening, of about 2%, which represents an improvement in their nutritional properties and provides an acceptable sensory profile.

Salahuddin, *et al* [78] studied the incorporation of maida, potato and soya as binders on the quality of kebabs from sheep, goat, chicken and buffalo meat under hot, chilled and frozen conditions of handling. Significantly higher yields were observed in kebabs with maida compared to kebabs with potato and soya. Emulsion stability values of meat formulations with maida were significantly lower than formulations with potato and soya. Comparatively better yield and acceptability of kebabs was observed with charbroiling rather than roasting. Zyl-H-Van and Zayas [98] used sorghum flour as meat replacer in frankfurters at the level of 2.5% (1:1 hydration w/w) and found no significant effect of sorghum flour on colour, firmness, shear force values, moisture, protein, fat contents and yield of frankfurters. Further, Zyl-H-Van and Zayas [97] measured characteristics of frankfurters extended

with sorghum flour at levels of 2, 3.5 and 5% and observed no significant influence of sorghum flour on pH, proximate composition, mechanical, sensory or shelf life measurements of frankfurters. Storage of frankfurters at  $6\pm 1^{\circ}\text{C}$  for 40 days also had no effect on sensory properties of frankfurters. Jimenez-Colmenero, *et al* [43] studied functional properties of sorghum flour as an extender in ground beef patties formulated with 20% fat and sorghum flour at levels of 2, 4 and 6% (10, 20 and 30% as rehydrated 1:4 with water). They found that patties containing sorghum flour had higher pH, greater yield, reduced cooking losses, less shrinkage in diameter and smaller increase in thickness than those without sorghum flour. Shear force, meat aroma and flavour of cooked patties were decreased as sorghum flour levels were increased while sorghum aroma, flavour and tenderness of cooked patties were increased with increase of sorghum flour levels. However, juiciness scores of cooked patties were not affected.

Titov, *et al* [90] reported that a hydrated barley (1:3) formulation in poultry meat sausage improved juiciness and biological value by 25-30% than the control at same fat level (10-15%). Shand [83] studied the efficacy of hull-less waxy barley and normal starch barley in ultra low-fat pork bologna sausages and concluded that hull-less waxy barley at 4% level had better texture and sensory properties. Bond [16] prepared beef patties with incorporation of 10% barley into 90/10 (% lean/fat) beef mince and found better acceptability of product in both young and adult consumers with respect to appearance, flavour and texture. Moreover, aerobic plate counts indicated that after 6 days of refrigerated storage the beef barley patty did not spoil any faster than controls. Bond, *et al* [17] studied the physical, chemical and shelf life characteristics of low-fat ground beef patties formulated with waxy hull-less barley and they found that the low-fat beef barley patty had substantially higher cooking yields. Beef barley burger on texture profile analysis by instron was found to be less chewy, springy, cohesive, gummy and hard than controls. They also reported that low-fat ground beef patties formulated with 10% hydrated cracked waxy hull-less barley was found to be more juicy, soft and less chewy and crumbly than control. Kumar and Sharma [54] studied the barley flour as fat replacer in low-fat pork patties and standardized the optimum level of barley flour as 4%. Kumar and Sharma [55] also reported successful utilization of barley flour as extender in chicken meat patties.

Abdel-Aal, *et al* [1] reported that addition of rice improved lysine concentration, amino acid score and the computed PER. El-Sayed, *et al* [34] compared rice flour with its protein isolate as a meat extender in sausages at 20, 30 and 40% levels. Sensory analysis showed rice protein isolates to be preferable to rice flour at all substitution levels. Johnson, *et al* [46] and Vickery and Rogers [93] reported on the use of cooked rice and rice flour as fat replacer. Yoo, *et al* [96] reported on the texturizing nature of rice flour while Minerich, *et al* [61] and Moharram, *et al* [63] provided the economic formulation of beef burger and beef patties respectively with rice flour as an extender. Nag, *et al* [64] studied the efficacy of rice flour as an extender in chicken nuggets and found that emulsion stability and cooking yield were improved while shear force value, proximate composition parameters and sensory attributes showed a declining trend with increase of extension levels. However, sensory scores of the product were comparable to control up to 5% extension and highly desirable up to 10% extension. Kim, *et al* [52] studied effect of rice fibre (RF) and rice bran oil (RBO) on restructured beef roasts as natural additives. Beef roasts containing either RF or RF/RBO had higher oxidative stability ( $P<0.05$ ) during storage at  $4^{\circ}\text{C}$  than did beef roasts without additives (control). The TBARS values, the saturated fatty acid/unsaturated fatty acid ratio (SFA/UFA) and the 7-ketocholesterol content of beef roasts with RF and RF/RBO were lower ( $P<0.05$ ) than those of controls during storage (0, 4 and 8 days). Vitamin E vitamers and UFA were higher than those of controls. Preliminary sensory data indicated beef roasts containing RF and RBO were acceptable to consumers. Kumar and Sharma [53] also reported successful utilization of pressed rice flour as an extender in chicken meat patties.

Non-meat proteins from a variety of plant sources such as soy proteins [41, 69, 70], buck wheat protein [10], samh flour [33], common bean flour [31] and bengal gram, green gram and black bean flours [64]

and corn flour [81] have been used as binders and extenders in comminuted meat products to improve the quality and reduce the production costs. Their prudent incorporation could result in improvement of meat products with inconsequential adverse effects. Bhat and Pathak [15] added green gram to chicken shish kebabs and observed a significant increase in cooking yield and emulsion stability without any significant loss of sensory properties. Randall, *et al* [72] reported that firmness, rupture force and resistance decreased with increased replacement of various additives in meat emulsion systems. Comer [24] studied the functionalities of six non-meat extenders and suggested that these had positive effects upon cooking stabilities but a negative influence on texture. Comer, *et al* [25] reported that all fillers, studied in a comminuted meat product, improved stability and textural firmness. There was evidence of interaction between soluble meat and vegetable proteins. The fillers appeared to increase frequency of fat agglomeration while improving stability. Bawa, *et al* [6] studied possible interactions upon combining different meat systems with various types of fillers and extenders and reported significant interactions among extenders and meat systems for EC and ES. Dzudie, *et al* [31] studied common bean flour as an extender in beef sausages and observed that water holding capacity (WHC) and pH increased and cooking losses decreased with increasing levels of added CBF in the emulsions, whereas shear force and hardness of the cooked products decreased. Serdaroglu, *et al* [82] evaluated the quality of low-fat meatballs extended with black eye bean flour (BBF) and found that BBF resulted in greater cooking yield, fat retention, water holding capacity (WHC) and moisture retention values and had lower reduction in diameter. According to sensory evaluation results all meatball treatments had high acceptability and received high scores. Prinyawiwatkul, *et al* [71] optimized acceptability of chicken nuggets containing fermented cowpea flour and observed that flavour and texture acceptability correlated highly with overall liking of nuggets. Products containing 20% FCF were unacceptable and nuggets containing a mixture of 2.5% FCF were as acceptable as the control, with a sweet, chicken flavour which suggested market potential for such poultry products. Modi, *et al* [62] studied the quality of buffalo meat burger containing decorticated green gram flour as binder. The burgers consisted of optimized quantities of roasted or unroasted legume flour, spices and common salt. Formulations with roasted flours registered lower thiobarbituric acid (TBA) values (mg malonaldehyde/kg sample) of 0.6–1.5 as against 0.6–2.1 for unroasted flours before frying. The burgers prepared with green gram flour as binder were organoleptically acceptable even after storage at  $-16\pm 2$  °C for 4 months. Rao and Reddy [73] evaluated the effect of black bean flour on the quality characteristics of chicken meat loaves and observed that there was significant reduction ( $P<0.01$ ) in cooking losses, extract release value and higher emulsion stability and pH of loaves, whereas there was a significant increase ( $P<0.01$ ) in moisture, crude protein and the scores for colour, flavour tenderness and overall acceptability throughout the period of 12 days of storage. Modi, *et al* [62] studied the quality of buffalo meat burger containing decorticated black bean flour as binder. The burgers consisted of optimized quantities of roasted or unroasted legume flour, spices and common salt. Inclusion of roasted black bean flour registered the highest yield of 95.7%, lowest shrinkage of 5% and lowest fat absorption of 26.6% on frying. However, the burger with black bean *dhal* (dehulled split legume) flour had better sensory quality attributes comparatively. Formulations with roasted flours registered lower thiobarbituric acid (TBA) values (mg malonaldehyde/kg sample) of 0.6–1.5 as against 0.6–2.1 for unroasted flours before frying. The burgers prepared with black bean as binder were organoleptically acceptable even after storage at  $-16\pm 2$  °C for 4 months.

Todd, *et al* [91] added pure cellulose (Solka-Floc), microcrystalline cellulose (Avicel) and a soluble gum (Nutriloid Fiberplus) to ground pork at 3.5% and 7.0% based on total dietary fibre content of each ingredient. Texture and cooking characteristics were determined on the patties from all treatments and compared to a control. The two cellulose products at 3.5% most closely resembled the control. The two cellulose products at 7.0% exhibited more hardness, whereas the gum products at 3.5% and 7.0% showed less springiness (elasticity). Cooking losses declined as fibre concentration increased from 3.5% to 7.0% for the cellulose products, but increased for the gum products. The Avicel products at

3.5% and 7.0% and Solka-Floc product at 7.0% exhibited significantly less change in diameter (patty shrinkage).

## Conclusions

Meat and meat products can be modified by adding fibre sources to decrease the possibility of chronic diseases associated with them. The use of these ingredients in meat products offers processors the opportunity to improve the nutritional and health qualities of their products.

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