Meat Products as Functional Foods: A Review

JOSE M. FERNÁNDEZ-GINÉS, JUANA FERNÁNDEZ-LÓPEZ, ESTRELLA SAYAS-BARBERÁ, AND JOSE.A. PÉREZ-ALVAREZ

ABSTRACT: Numerous studies have sought to demonstrate the possibility of changing the image of meat and meat products from the traditionally accepted image to one of healthy living thanks to the addition (vegetables, extracts, fibers, and so forth), elimination (fats), and reduction (additives) of different ingredients. This article presents a revision of studies published in recent years on the topic and looks at possible future trends in the sector, analyzing the changes that have occurred in the traditional meat industry as global forces in the agro-food industry direct it more and more to the design and production of functional foods.

Keywords: meat products, functional foods, functional ingredients

Introduction

The trend toward functional foods has led to the publication of several articles describing studies of the effects of including 1 or more ingredients with functional properties in various types of food, within which meat and meat products deserve special attention. The object of including functional ingredients in the case of meat is not only concerned with providing it with certain desirable properties but also an attempt to change its image in these health-conscious days.

The meat industry is 1 of the most important in the world and, whether as a result of consumer demand or because of the ferocious competition in the industry, research into new products is continuous. However, such research and the launch of new products is directed at providing healthy alternatives to what has frequently been accused of causing a variety of pathologies (Jiménez-Colmenero 2000). This unfortunate image derives mainly from the content of fat, saturated fatty acids, and cholesterol and their association with cardiovascular diseases, some types of cancer, obesity, and so forth.

Regarding obesity, it is very important to understand how meat or meat products affects biological and physiological mechanisms of appetite, satiety, and long-term behavior. Meat and meat products show highly satiating characteristics and, in this respect, functional foods could be a food-related solution because these types of products could be designed to be less calorifically dense and while remaining more highly satiating and tasty. In this way, the food industry in general, the meat and related products industry in particular, could contribute to making lives easier and more active.

Meat is associated with cholesterol, and although it is now accepted that the dietary intake of cholesterol has little bearing on plasma cholesterol, for consumers this is another negative influence on meat's health image (Higgs 2000).

In some cases, the consumer is confused by multiple messages from multiple sources, public skepticism about expert opinion, the public misunderstanding of reports on scientific findings and results, increased media coverage accompanied by recommendations for corporate marketing strategies and health claims, and competing real-life and lifestyle demands. Furthermore, food packaging could also have a very important influence on food intake (MacAulay and Newsome 2004).

MS 20040498 Submitted 7/26/04, Revised 8/30/04, Accepted 9/10/04. *The authors are with Dept. de Tecnología Agroalimentaria, Escuela Politécnica Superior de Orihuela, Univ. Miguel Hernández, Orihuela, Alicante, Spain. Direct inquiries to author Fernández López (E-mail: j.fernandez@umh.es).*

The underlying idea behind functional food is to reduce the prevalence of chronic diseases by curbing the consumption of habitually consumed foods. The formulation of foods according to the beneficial effects that their non-nutritional ingredients may have for the consumer has become an area of great interest for large food companies, including the meat sector (Vasconcellos 2001).

Although there is no exact definition of what a functional food is and many consider that it is a concept still under development, among the most widely accepted definition from a European point of view is that mentioned by Robertfroid (Pascal and Collet-Ribbing 1998), namely that "a food may be considered functional if it contains a component (be it nutrient or not) with a selective effect on one or various functions of the organism, whose positive effects justify that it can be regarded as functional (physiological) or even healthy." A food can be regarded as functional if it is satisfactorily demonstrated to beneficially affect 1 or more target functions in the body, beyond adequate nutritional effects, in a way that is relevant to either improved health or well-being and/or to a reduction in the risk of disease. A functional food must remain food and it must demonstrate its effects in amounts that can normally be expected to be consumed in the diet: it is not a pill or a capsule, but part of the normal food pattern (Dipplock and others 1999). European consumers are more critical and less unconditional than Americans with this type of product because Europeans have recently suffered a sequence of food safety scares (BSE, foot-and-mouth disease, and so forth). Also, among countries, perception is very different; for example in Denmark, consumers are very suspicious of functional foods, which they judge as "unnatural and impure" (Jonas and Beckmann 1998).

As far as meat is concerned, the modifications to which it may be subjected to confer functional properties on it are based on modifications to the feed an animal receives or on postmortem manipulation of the carcass. By the 1st means, the lipid, fatty acid, and vitamin E content can be modified, whereas by the 2nd, fat can be removed by mechanical processes. Regarding meat products, efforts are mainly directed toward their reformulation by modifying the lipid and fatty acid content, and/or by adding a series of functional ingredients (fiber, vegetal proteins, monounsaturated or polyunsaturated fatty acids, vitamins, calcium, phytochemicals, and so forth) (Jimenez-Colmenero and others 2001). Meat and meat products are essential for a balanced diet, although it must also be remembered that they are susceptible to modifications to give them a "healthier" appearance.

The object of this article is to evaluate the effect of adding functional ingredients on the physical, chemical, and sensory characteristics of foods, especially meat and its related products, as understood from recently published scientific articles (Table 1).

Functional modifications in meat and meat products

Meat and meat products are essential in the diet of developed countries. Their principal components, besides water, are proteins and fats, with a substantial contribution of vitamins and minerals of a high degree of bioavailability. 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 foods can be obtained which, without altering their base, are considered "healthy."

Modification of the fatty acid and cholesterol levels in meat

Meat is in a major source of fat in the diet, especially of saturated fatty acids (SFA), which have been implicated in diseases associated with modern life, especially in developed countries. The ratio of n-6:n-3 polyunsaturated fatty acids (PUFA) is also a risk factor in cancers and coronary heart disease, especially the formation of blood clots leading to a heart attack.

Levels of n-3 PUFA in pigs fed a linseed diet produced higher levels of thiobarbituric acid reactive substances (TBARS) after conditioning for 10 d followed by simulated retail display for a further 7 d, although the display period had no impact on the sensorial characteristics such as muscle color (saturation) (Wood and others 2003).

The selection of breeds and genetic lines within breeds, changes in animal feeding practices, including some feed additives (probiotics, antibiotics, and so forth), and intervention in animal metabolism (anabolic implants, β-agonist, growth hormone, etc.) are the main tools used to achieve a reduction in carcass fat content (Chizzolini and others 1999), although many such practices are not authorized in the European Union.

When Velasco and others (2004) compared unweaned lambs and lambs weaned at 40 d of age, fattened at pasture and slaughtered at 28 kg live weight, to observe the effect on meat quality and fatty acid composition, the weaning status was seen to affect the fatness and quality characteristics of the meat (of lambs raised at pasture) more than the type of feed. A further decrease in the intramuscular fat content would decrease meat quality attributes, especially juiciness and flavor, which are already impaired in some cases (Chizzolini and others 1999). Variations in fatty acid composition have an important effect on firmness or softness of the fat in meat, especially the subcutaneous and intermuscular (carcass) fats but also the intramuscular (marbling) fat.

The effect of fatty acids on meat shelf life is explained by the propensity of unsaturated fatty acids to oxidise, leading to the development of rancidity as display times increases. Changes in fatty acid composition have not been directly linked to changes in myoglobin oxidation and muscle color in many of the pork meat studies reported (Wood and others 2003). In studies of rabbit meat, Dal Bosco and others (2004), confirmed that meat enrichment in n-3 PUFA did not cause any increase in the oxidation level. The α-linolenic acid–vitamin E diet favored the accumulation of long-chain polyunsaturated n-3 in the meat and improved its oxidative stability and consequently its nutritional value. Enser and others (2000), in studies about feeding linseed to increase the n-3 PUFA in pork meat, confirmed the potential of pig meat to supply valuable n-3 PUFA to the human diet, finding that it may be readily manipulated to increase the concentrations.

Conjugated linoleic acid (CLA) has been recognized as having anticarcinogenic and antioxidative properties in several animal models. Hur and others (2004) reported that the concentration of CLA was significantly increased by the substitution of fat. Storage for 14 d had little effect on the CLA concentration in beef patties. Substituted CLA sources for fat improved the color stability possibly by inhibition of lipid oxidation and oxymioglobin oxidation.

Addition of vegetal oils to meat products

Olive oil is the most monounsaturated vegetable oil. It has a high biological value, and its consumption is related to a decreased risk of heart disease and breast cancer (Pappa and others 2000). Vegetable oils have also been used as partial substitutes of pork backfat in low-fat frankfurters and other types of cooked product giving rise to products with more adequate fatty acid profiles and cholesterol levels than traditional ones (Muguerza and others 2001).

Studies of Pappa and others (2000) concerning the use of olive oil to replace (0% to 100%) pork backfat for the production of low-fat frankfurters, showed that the higher levels of olive oil had the lowest overall acceptability, although color attributes were unaffected.

Muguerza and others (2001) manufactured traditional Spanish sausage, replacing 0% to 30% of pork backfat by pre-emulsified olive oil. The oleic and linoleic acid levels increased and the cholesterol content was reduced, while the sensorial characteristics, (texture and color) were comparable with those of commercial products. The results pointed to the possibility of replacing pork backfat with olive oil (up to 25%) to increase the nutritional status.

Ansorena and Astiasarán (2004a) reported that the addition of olive oil to sausages was more effective than using vacuum-storing methods in avoiding lipid oxidation during storage and also increased the monounsaturated fatty acids fraction (MUFA).

Other studies (Muguerza and others 2002) on fermented sausages found that the replacement of 20% pork backfat with olive oil does not affect the weight losses and makes the sausages lighter in color and more yellow. The product has an acceptable odor and taste but unacceptable appearance because of the intensively wrinkled surfaces and the development of casing hardening. The same authors (Muguerza and others 2003b) found that the replacement of 20% pork backfat by olive oil in high and reduced fat Greek sausages led to significant decrease in the oxidation process and significantly increased the MUFA content.

In their studies into "salami" products, Severini and others (2003) found that the partial substitution of pork backfat by extra virgin olive oil did not substantially affect the chemical, physical, and sensory characteristics of the products, with the exception of water activity and firmness. The addition of the extra virgin olive oil, which is rich in unsaturated fatty acids, did not reduce the shelf life in terms of lipid oxidation, probably due to the antioxidant effect of both polyphenols and tocopherols. Sensory analyses did not point to differences from the traditional formulation.

An alternative to using this vegetable oil, which has a high unsaturated fatty acid content and is liquid at room temperature, is to use interesterified vegetable oils (IVOs). These oils can be used as a fat replacer to modify the fatty acid composition of frankfurters and Turkish type salami without any detrimental changes in sensory characteristics. Vural and others (2004) produced frankfurters with IVOs prepared from palm, cottonseed, and olive oils and found that replacing beef fat (10%) with IVOs (60% to 100%) led to a significant increase in the oleic and linoleic acid content and the PUFA: SFA ratio without any change in appearance, color, texture, flavor, or other sensory characteristics.

Other studies have described the addition of high oleic sunflower oil to low-fat frankfurters as a source of monounsaturated fat. Yilmaz and others (2002) found that the resulting product was healthier due the higher contents of unsaturated and essential fatty acids, without any negative sensory characteristics.

Linseed oil is another source of fat. Ansorena and Astiasarán (2004b) found that the substitution of pork backfat with linseed oil in the manufacture of dry-fermented sausages decreased the n-6:n-3 ratio (from 14.1 to 2.1) as a consequence of the increase in α-linolenic acid. These authors affirmed that this had a relevant influence on the nutritional quality of the products, without substantially modifying the flavor or oxidation.

Addition of soy

Plant-derived proteins from soybeans have been used in traditional comminuted meat products (30% fat) as meat replacements. Soy proteins (flours, concentrates, and isolates) are more commonly used in processed meat products for their functional properties and relatively low cost compared with lean meat (Chin and others 1999). Soy proteins have been incorporated in these products for their water-binding and fat-binding ability, enhancement of emulsion stability, and increased yields (Chin and others 2000).

Soya protein lowers blood lipid levels compared with animal protein. In 1999, the U.S. Food and Drug Administration approved a health claim that diets low in saturated fat and cholesterol that include 25 g soy protein per day may reduce the risk of heart disease (Sadler 2004). Intact soy (with isoflavones) has a greater effect on reducing low-density lipoprotein (LDL) and total cholesterol concentrations than extracted soy.

Soy isoflavones include compounds such as daidzin, genistin, daidzein, and genistein. However, it has recently been recognized that the isoflavones contained in vegetable proteins may have a detrimental impact on mammals that consume the vegetable protein.

Soy oil also contains approximately 0.2 g plant sterols per 100 g. Plant sterols and plant stanols are associated with lowering plasma LDL cholesterol at intakes of 2 to 3 g/d (Ferrari and Torres 2003; Sadler 2004). Soy has been described as being useful in the prevention and treatment of cancer, osteoporosis, and in the relief of menopausal symptoms (Jiménez-Colmenero and others 2001; Halsted 2003).

Some researches have studied the use of soy derivates in meat products. Porcella and others (2001) studied the addition of Soy protein isolates (SPI) (2.5%) to chorizo raw sausage and found that it prevented drip loss of vacuum-packaged chorizos during refrigerated storage and did not affect the organoleptic and microbiological properties during shelf life of 14 d.

Soy protein isolate has been added in low-fat bologna, too. Chin and others (2000) characterized this product and concluded that SPI (2%) can be incorporated as fat replacer without any detrimental physicochemical and textural characteristics being noted in the product, except for color values. The addition of SPI did not seem to change the ultrastructure of the meat protein gel matrix, and no interactions were noted with meat proteins. In other studies by the same authors (Chin and others 1999), 4.4% SPI resulted in a softer texture of low-fat bologna and did not affect the another chemical parameters.

Feng and others (2003) incorporated thermally/enzymatically obtained soy protein isolates (2%) in pork frankfurters. They concluded that heat and enzyme-hydrolyzed soy proteins affected texture properties differently, the 1st improving hardness and 2nd reducing hardness, cohesiveness, and breaking strength.

The replacement of pork backfat with soy oil has also been studied. Muguerza and others (2003a) reported that the addition of soy oil did not modify the percentage of water or protein and the pH in fermented sausages. With the addition of pre-emulsified soy oil, cholesterol hardly decreased and oxidation was not modified. Saturated and monounsaturated fatty acids decreased, and polyunsatutared increased due the significant increase in linoleic and α-linolenic acids. In the texture profile analyses, the sensory analysis and color did not show significant differences from commercial products.

Another product, soy protein concentrate mixed with κ-carrageenan (0% to 3%), was investigated in comminuted scalded sausage (Pietrasik and Duda 2000). The addition favorably affected the water-holding capacity and thermal stability of the processed sausages regardless of the fat content. It did not improve the textural parameters, and no significant influence on color parameters was observed.

Addition of natural extracts with antioxidant properties

Lipid oxidation is one of the causes for the deterioration of meat and derivatives because their appearance determines the onset of a large number of undesirable changes in flavor, texture, and nutritional value (Gil and others 2001). The rate of lipid oxidation can be effectively retarded by the use of antioxidants. Synthetic antioxidants were widely used in the meat industry, but consumer concerns over safety and toxicity pressed the food industry to find natural sources (Coronado and others 2002). Natural antioxidants extracted from plants such as rosemary, sage, tea, soybean, citrus peel, sesame seed, olives, carob pod, and grapes can be used as alternatives to the synthetic antioxidants because of their equivalent or greater effect on the inhibition of lipid oxidation (Tang and others 2001). The human intake of green tea decreases total cholesterol, increases the high-density lipoprotein (HDL) fraction, and decreases lipoprotein oxidation (Tang and others 2001; Ferrari and Torres 2003).

The addition of tea catechins to cooked red meat and poultry was studied by Tang and others (2001), who found that addition at 300 mg/kg minced muscle significantly inhibited the pro-oxidative effect of NaCl and controlled lipid oxidation in cooked muscle patties. The high affinity of tea catechins for lipid bilayers of muscle and their radical scavenging abilities may provide a possible mechanism to explain the inhibition of lipid oxidation in cooked muscle food.

The functional properties of raw and cooked pork patties with added irradiated green tea leaf extract was studied by Jo and others (2003). This extract did not have negative effects on the physical and sensory properties and had beneficial biochemical properties; the researchers concluded that irradiated green tea extract powder can be used to add functional properties to pork patties.

Jo and others (2003) added irradiated, freeze-dried green tea to cooked pork patties. The results show that this ingredient had no negative effects on the physical and sensory properties. Lipid oxidation was lower and showed less cooking loss. Also, the patties with added green tea leaf extract had beneficial biochemical properties.

Another extract used in meat products is rosemary, from whose leaves a large number of phenolic compounds with antioxidant activities have been isolated. These include carnosol, carnosic acid, rosmanol, epirosmanol, isorosmanol, rosmarinic acid, rosmaridiphenol, and rosmariquinone (Gil and others 2001; Fernández-López and others 2003). Coronado and others (2002) manufactured wiener sausages with this extract, and no lipid oxidation was observed in the product during long-term frozen storage. Wieners containing rosemary appeared to have slower rates of oxidation than those without antioxidant.

Sodium chloride control

Due to the role of sodium in the development of hypertension in sodium-sensitive individuals, public health and regulatory authorities have recommended a reduced dietary intake of sodium choride. However, intake still exceeds the nutritional recommendations in many countries (Ruusunen 2003a).

The main source of sodium chloride in meat products is salt (NaCl), and its reduction in meat products is an important goal for decreasing overall dietary sodium. Because salt contributes to water and fat binding in meat products, its reduction has an adverse effect on these parameters increasing cooking loss and weakening the texture (Ruusunen 2003a, 2003b).

Although meat as such is relatively poor in sodium, containing only 50 to 90 mg of sodium per 100 g, the sodium content of meat derivatives is much higher because of the salt content, which may reach 2% in heat-treated products and as much as 6% in uncooked cured products, in which drying (loss of moisture) increases the proportion even further. Estimates taking eating habits into account suggest that approximately 20% to 30% of common salt intake comes from meat and meat derivatives (Jiménez-Colmenero and others 2001).

Ruusunen and others (2003a) described the physical and sensory properties of low-salt phosphate-free frankfurters and concluded that when the frankfurters were made without phosphate, additional nonmeat ingredients (modified tapioca starch, sodium citrate, and wheat bran) were needed when the salt contents was below 1.5%. Salt directly affects frying loss, water and fat binding, firmness, saltiness, and flavor intensity.

In other research, Ruusunen and others (2003b) evaluated the quality characteristics of low-salt bologna-type sausage manufactured with sodium citrate, carboxymethyl cellulose, and carrageenan. The results show that in low-salt sausages containing less than 1.4% NaCl, the use of these ingredients decreased frying loss and increased saltiness, but the conclusion was that in low-salt sausages, no additive alone is recommended. In the same study, salt affected frying loss, firmness, saltiness, juiciness, and flavor intensity.

Gimeno and others (2001) studied calcium ascorbate as a potential partial substitute for NaCl in dry-fermented sausages, in which substitution caused higher acidification as a result of greater lactic acid bacteria development, probably due to the presence of calcium. Partial replacement of NaCl by calcium ascorbate seems to be a viable way of decreasing sodium in dry-fermented sausages. It would imply enrichment in ascorbate and calcium with advantages from the nutritional point of view. The salt reduction affects L^*, a^*, and b^* CIELAB coordinates (Commission Internationale de l'Eclariage) and also affects hardness, gumminess, and chewiness.

Addition of fish oils

Oils in the form of n-3 polyunsaturated fatty acids occur mainly in cold water fish, whereas n-6 polyunsaturated fatty acids come mainly from plants and saturated fatty acids from animal sources. Diets in which cold water fish such as mackerel (*Scomber scombrus*), salmon (*Salmo salar*), halibut (*Hippoglossus hippoglossus*), and trout *(Oncorhynchus mykiss)* are the main staple are associated with reduced incidence of coronary heart disease but an increased risk of hemorrhage (Halsted 2003).

Epidemiological, clinical, and biochemical studies have provided a great deal of evidence about the protective effect of n-3 polyunsaturated fatty acids against some common cancers such as breast and colon cancer, rheumatoid arthritis, inflammatory bowel diseases, and cardiovascular diseases (Hoz and others 2004). Levels of dietary fish oil and dietary antioxidant significantly influence the n-3 fatty acid and cholesterol content of meat lipids (Jeun-Horng and others 2002).

In the studies of Jeun-Horng and others (2002) about the addition of fish oil (2% to 4%) to the diet of chickens used to make chicken frankfurters, no significant differences were found in pH, cooking yield and moisture, fat, protein, ash and cholesterol contents, and sensory quality. These frankfurters had higher contents of eicosapentaenoic acid (EPA) and docosahexanoic acid (DHA), but a lower content of n-6 fatty acids.

Hoz and others (2004) manufactured salchichon using backfat and meat enriched in polyunsaturated n-3 fatty acids and α-tocopherol, concludeing that it is possible to manufacture dry-fermented sausages enriched in n-3 PUFAs without adverse effects on its composition, lipid stability, textural, and sensory properties.

Addition of vegetal products

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 fiber, 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 (Jiménez-Colmenero and others 2001). 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 (Sadler 2004).

Modi and others (2003) studied the effect of adding different decorticated legume flours to buffalo meat burgers and showed that the inclusion of roasted black gram flour led to lower thiobarbituric acid values before frying and found the burger organoleptically acceptable even after storage at –16 ± 2 °C for 4 mo.

Nuts provide high levels of protein. Several studies have demonstrated an inverse association between nut consumption and the risk of cardiovascular diseases (CHD). Although nuts are high in fat, they contain a high proportion of unsaturated fats, including monounsaturated fats, which can contribute a cholesterol-lowering effect when used to replace dietary fatty acids and/or carbohydrate. Walnuts, peanuts, and almonds are also a source of α-linolenic acid, as are mycoprotein and soya oil. Nuts also contain dietary fiber and various bioactive compounds such as plant sterols, which have cholesterol-lowering properties (Halsted 2003; Sadler 2004).

The addition of walnuts to restructured beef steak was studied by Jimenez-Colmenero and others (2003). The results showed that the addition of walnuts affects the cooking properties, color, texture, and sensory attributes, making the product softer and providing it with better water-binding properties. Product morphology studies suggested that walnut interferes with the formation of protein network structures.

Addition of fiber

Epidemiological research has demonstrated a relationship between a diet containing an excess of energy-dense foods rich in fats and sugar and the emergence of a range of chronic diseases, including colon cancer, obesity, cardiovascular diseases, and several other disorders (Best 1991; Kaefersteins and Clugston 1995; Beecher 1999) and, thus, an increase in the level of dietary fiber in the daily diet has been recommended (Eastwood 1992; Johnson and Southgate 1994). The presence of fiber in foods produces a diminution in their caloric content.

Fiber 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 (Cofrades and others 2000). Various types of fiber have been studied alone or combined with other ingredients for formulations of reduced-fat meat products, largely ground and restructured products (Desmond and others 1998; Mansour and Khalil 1999), and meat emulsions (Claus and Hunt 1991; Chang and Carpenter 1997; Grigelmo-Miguel and others 1999).

In studies by Yilmaz (2004), rye bran was used 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 authors concluded that this type of fiber can be used as dietary fiber source.

Another source of fiber is oat. Many of the characteristics of oat fiber such as its water-absorption capacity could potentially benefit products such as fat-free frankfurters and low-fat bologna. Oat products have also achieved a very positive consumer image because of the health benefits that have been associated with their consumption. Oat was added by Steenblock and others (2001) to determine the effects on the quality characteristics of light bologna and fat-free frankfurters. Different types of oat fiber were used, high absorption (HA) or bleached oat (BL) fiber at levels up to 3%. The results indicated that the addition of both types of oat fiber produced greater yields and a lighter red color. Purge was reduced with oat fiber at 3%. Product hardness increased for bologna. It has been reported that oat bran and oat fiber provide the flavor, texture, and mouthfeel of fat in ground beef and pork sausages (García and others 2002).

The components of dietary fiber include fructooligosaccharides (FOS), a generic name for all nondigestible oligosaccharides composed mainly of fructose. The effect of a short-chain FOS on cooked sausages was studied by Cáceres and others (2004). The addition did not affect the pH, a_w or weight losses because the presence of soluble dietary fiber (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 fiber 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.

Another SDF is inulin, which can be used as a fat substitute mainly in nonmeat foods (cakes, chocolates, dairy products, spreads) because of its contributions to better mouthfeel, enhanced flavor, and low-caloric value (1.0 kcal/g). Mendoza and others (2001) 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. 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.

Epidemiological studies have shown that the consumption of fruits and vegetables imparts health benefits, for example, reduced risk of coronary heart disease, stroke, and certain types of cancer. Apart from the dietary fiber, fruits and vegetables contain health benefits that are mainly attributed to organic micronutrients such as carotenoids, polyphenolics, tocopherols, vitamin C, and others (Schieber and others 2001).

Inner pea fiber was identified as an ingredient capable of retaining high fat and water in ground beef. Inner pea fiber is manufactured from the inner cell walls of yellow field peas and contains approximately 48% fiber, 44% starch, and 7% protein. This fiber may improve the sensory properties of lower fat ground beef by retaining substantial amounts of both the moisture and fat that are normally lost during cooking. This source was added in a dry form by Anderson and Berry (2000) to lower-fat beef patties (10% and 14%), in which it improved tenderness and cooking yield without having negative effects on juiciness and flavor.

Another important source of fiber is fruits, which can also be obtained as by-products of plant food processing. Citrus byproducts (lemon albedo and orange fiber powder) have been added, at different concentrations, to cooked and dry-cured sausages with excellent results (Aleson-Carbonell and others 2003, 2004; Fernández-Ginés and others 2003, 2004; Fernández-López and others 2004).

Lemon albedo was added at different concentration (2.5% to 10%) to cooked sausages (Fernández-Ginés and others 2004) and dry-cured sausages (Aleson-Carbonell and others 2003, 2004). 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.

Orange fiber powder was added at different concentrations (0.5% to 2%) to 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 color. Citrus fiber at all concentrations made the products harder and less springy and chewy. All the samples had a similarly good score in the sensory analysis, except the sample with 2% citrus fiber (Fernández-Ginés and others 2003).

García and others (2002) studied the effect of adding cereal and fruit fibers on the sensory properties of reduced-fat, dry-fermented sausages. The cereal (wheat and oat) and fruit (peach, apple, and orange) dietary fibers were added at 1.5% and 3% concentrations. The addition of dietary fiber from cereals and fruits at 1.5% resulted in sausages with a final fiber content, after ripening, of about 2%, which represents an improvement in their nutritional properties and provides an acceptable sensory profile. Higher amounts of fiber (3%) increased the hardness, resulting in products with a lower sensory quality. The best results in this study were obtained with sausages containing 10% pork backfat and 1.5% fruit fiber. The orange fiber provides the best results with sensory properties similar to those of conventional sausage.

Conclusions

Meat and meat products can be modified by adding ingredients considered beneficial for health or by eliminating or reducing components that are considered harmful. The use of these ingredients in meat products offers processors the opportunity to improve the nutritional and health qualities of their products. But sometimes (above all when these ingredients are added at high concentrations) their use results in products with lower sensory and physicochemical quality. The results suggest that many ingredients can be used in the meat industry to add functional properties to meat products, and further research is needed to understand their interactions with meat products constituents and thus to improve their safety in potential industrial applications.

Acknowledgments

The financial support by the Spanish Conselleria de Cultura, Educación y Deporte (Generalitat Valenciana) through the Project GV04B-679 is gratefully acknowledged.

Table 1—Recent articles about meat and meat products with functional ingredients

Meat product	Type of ingredient	Impact on product	Reference
Dry-fermented sausages	Calcium ascorbate	Decrease sodium supply	Gimeno and others 2001
	Cereal and fruit fibers	Increase fiber levels	García and others 2002
	Extra-virgin olive oil	Did not affect on chemical, physical, and sensory characteristics. Did not reduce lipid oxidation	Severini and others 2003
	Inulin	Softer texture, tenderness, springiness, and adhesiveness. Improved nutritional properties	Mendoza and others 2001
	Linseed oil	Improved nutritional quality without substantially modifying flavor and oxidation status	Ansorena and Astiasarán 2004b
	Olive oil	Reduced cholesterol and increased MUFA and PUFA fractions. Lighter and more yellow sausages. Reduced oxidation	Muguerza and others 2001, 2002, 2003b
	Olive oil and antioxidants	Reduced lipid oxidation under vacuum storing	Ansorena and Astiasarán 2004a
	Polyunsaturated n-3 fatty acids and α-tocopherol	Did not effect composition, lipid stability, textural and sensory properties	Hoz and others 2004
	Soy oil	Reduced saturated fatty acids, increased linoleic and α-linolenic acids	Muguerza and others 2003a
	Soy protein isolate	Prevented drip loss	Porcella and others 2001
	Citrus fiber	Reduced residual nitrite levels. Did not modify sensorial properties	Aleson-Carbonell and others 2003, 2004
Cooked meat products	Citrus fiber	Improved nutritional properties. Increased fiber levels	Fernández-Ginés and others 2003, 2004
	Fish oil	Increased EPA and DHA content and reduced n-6 fatty acids	Jeun-Horng and others 2002
	Fructooligosaccharides	Hypocaloric and rich in dietary fiber	Cáceres and others 2004
	Konjac blends and soy protein	Did not modify physicochemical and textural characteristics, except color	Chin and others 2000
	Modified tapioca starch, sodium citrate, and wheat bran	Decreased frying loss. Improved water and fat binding	Ruusunen and others 2003a
	Oat fiber	Increased hardness and sensory toughness	Steenblock and others 2001
	Olive oil and pectin	Highest overall acceptabilityin 1.8% to 2.1% salt, 0% to 35% olive oil, and 0.25% to 0.45% pectin	Pappa and others 2000
	Rosemary extract and whey powder	Slowed rates of oxidation	Coronado and others 2002
	Sodium citrate, carboxymethyl cellulose, and carrageenan	Decreased frying loss and increased saltiness and firmness	Ruusunen and others 2003b
	Soy protein isolate and konjac blends	Affected texture and color	Chin and others 1999
	Soy protein/carrageenan mix	Affected water-holding capacity and thermal stability. Did not improve textural parameters	Pietrasik and Duda 2000
	Soy proteins	Affected textural properties	Feng and others 2003
	Tomato juice and sunflower oil	Increased unsaturated and essential fatty acids contents	Yilmaz and others 2002
	Tea catechins	Inhibited lipid oxidation	Tang and others 2001
	Rye bran	Lowered total trans fatty acids. Increased ratio of total unsaturated fatty acids to total saturated fatty acids	Yilmaz 2004
Fresh meat products	Walnuts	Acceptable physicochemical and sensory properties. Improved health benefits	Jiménez-Colmenero and others 2003
	Feeding linseed	Increased n-3 PUFA	Enser and others 2000
	Dietary linoleic acid and vitamin E	Improved nutritional properties	Dal Bosco and others 2004
	Conjugated linoleic acid	Improved color stability, inhibited lipid and oxymioglobin oxidation	Hur and others 2004
	Green tea	Improved biochemical properties	Jo and others 2003
	Legume flours	Lowered fat absorption on frying	Modi and others 2003
	Inner pea fiber	Improved tenderness and cooking yield	Anderson and Berry 2000

References

Aleson-Carbonell L, Fernández-López J, Sayas-Barberá E, Sendra E, Pérez-Alvarez JA. 2003. Utilization of lemon albedo in dry-cured sausages. J Food Sci 68:1826–30.

Aleson-Carbonell L, Fernández-López J, Sendra E, Sayas-Barberá E, Pérez-Alvarez JA. 2004. Quality characteristics of a non-fermented dry-cured sausage formulated with lemon albedo. J Sci Food Agric 84:2077-84.

Anderson ET, Berry BW. 2000. Sensory. Shear and cooking properties of lower-fat beef patties made with inner pea fiber. J Food Sci 65(5):805–10.

Ansorena D, Astiasarán I. 2004a. Effect of storage and packaging on fatty acid composition and oxidation in dry fermented sausages made with added olive oil and antioxidants. Meat Sci 67:237–44.

Ansorena D, Astiasarán I. 2004b. The use of linseed oil improves nutritional quality of the lipid fraction of dry-fermented sausages. Food Chem 87:69–74.

Beecher GR. 1999. Phytonutrients role in metabolism: effects on resistance to degenerative processes. Nutr Rev 57:3–6.

Best D. 1991. Whatever happened to fiber. Prep Foods 160:54–6.

Cáceres E, García ML, Toro J, Selgas MD. 2004. The effect of fructooligosacharides on the sensory characteristics of cooked sausages. Meat Sci 68:87–96.

Chang HC, Carpenter JA. 1997. Optimizing quality of frankfurters containing oat bran and added water. J Food Sci 62:194–202.

Chin KB, Keeton JT, Longnecker MT, Lamkey JW. 1999. Utilization of soy protein isolate and konjac blends in a low-fat bologna (model system). Meat Sci 53:45–57.

Chin KB, Keeton JT, Miller RK, Longnecker MT, Lamkey JW. 2000. Evaluation of konjac blends and soy protein isolate as fat replacements in low-fat bologna. J Food Sci 65(5):756–63.

Chizzolini R, Zanardi E, Dorigoni V, Ghidini S. 1999. Calorific value and cholesterol content of normal and low-fat meat and meat products. Trends Food Sci Technol 10:119–28.

Claus JR, Hunt MC. 1991. Low-fat, high added water bologna formulated with texture-modifying ingredients. J Food Sci 56:643–7.

Cofrades S, Guerra MA, Carballo J, Fernández-Martín F, Jiménez-Colmenero F. 2000. Plasma protein and soy fiber content effect on bologna sausage properties as influenced by fat level. J Food Sci 65:281–7.

Coronado SA, Trout GT, Dunshea FR, Shah NP. 2002. Antioxidant effects of rosemary extract and whey powder on the oxidative stability of wiener sausages during 10 months frozen storage. Meat Sci 62:217–24.

Dal Bosco A, Castellini C, Bianchi L, Mugnai C. 2004. Effect of dietary α-linolenic acid and vitamin E on the fatty acid composition, storage stability and sensory traits of rabbit meat. Meat Sci 66:407–13.

Desmond E, Troy DJ, Bucley J. 1998. Comparative studies on non-meat ingredients used in the manufacture of low-fat burgers. J Muscle Foods 9:221–4.

Dipplock AT, Agget PJ, Ashwell M, Bornet F, Fern EB, Robertfroid MB. 1999. Scientific concepts of functional foods in Europe: consensus document. Br J Nutr 81(Suppl 1):S1–S27.

Eastwood MA. 1992. The physiological effect of dietary fiber: an update. Ann Rev Nutr 12:19–35.

Enser M, Richardson RI, Wood JD, Gill BP, Sheard PR. 2000. Feeding linseed to increase the n-3 PUFA of pork: fatty acid composition of muscle, adipose tissue, liver and sausages. Meat Sci 55:201–12.

Feng J, Xiong YL, Mikel WB. 2002. Textural properties of pork frankfurters containing thermally/enzymatically modified soy proteins. J Food Sci 68(1):1220–4.

Fernández-Ginés JM, Fernández-López J, Sayas-Barberá E, Sendra E, Pérez-Álvarez JA. 2003. Effect of storage conditions on quality characteristics of bologna sausages made with citrus fiber. J Food Sci 68(2):710–5.

Fernández-Ginés JM, Fernández-López J, Sayas-Barberá E, Sendra E, Pérez-Álvarez JA. 2004. Lemon albedo as a new source of dietary fiber: application to bologna sausages. Meat Sci 67:7–13.

Fernández-López J, Fernández-Ginés JM, Alerón-Carbonell L, Sayas-Barberá E, Sendra E, Pérez-Álvarez JA. 2004. Application of functional citrus by-products to meat products. Trends Food Sci Technol 15:176–85.

Fernández-López J, Sayas-Barberá ME, Navarro C, Marín F, Pérez-Alvarez JA. 2003. Evaluation of the antioxidant potential of hyssop (*Hyssopus officinalis* L.) and rosemary (*Rosmarinus officinalis L.*) extract in cooked pork meat. J Food Sci 68:660–4.

Ferrari CKB, Torres EAFS. 2003. Biochemical pharmacology of functional foods and prevention of chronic diseases of aging. Biomedicine and Pharmacotherapy 57:251–60.

García ML, Domínguez R, Galvez MD, Casas C, Selgas MD. 2002. Utilization of cereal and fruit fibres in low fat dry fermented sausages. Meat Sci 60:227–36.

Gil MD, Bañón SJ, Cayuela JM, Laencina J, Garrido MD. 2001. Utilización de extractos de plantas como antioxidantes naturales en carne y productos cárnicos: revisión. Eurocarne 101:1–10.

Gimeno O, Astiasarán I, Bello J. 2001. Calcium ascorbate as a potential partial substitute for NaCl in dry fermented sausages: effect on color, texture and hygienic quality at different concentrations. Meat Sci 57:23–9.

Grigelmo-Miguel N, Abadía-Serós MI, Martín-Belloso OA. 1999. Characterisation of low-fat high-dietary fiber frankfurters. Meat Sci 52:247–56.

Halsted CH. 2003. Dietary supplements and functional foods: 2 sides of a coin? Am J Clin Nutr 77:1001–7.

Higgs JD. 2000. The changing nature of red meat: 20 years of improving nutritional quality. Trends Food Sci Technol 11:85–95.

Hoz L, D'Arrigo M, Cambero I, Ordóñez JA. 2004. Development of an n-3 fatty acid and α-tocopherol enriched dry fermented sausage. Meat Sci 67:485–95.

Hur SJ, Ye BW, Lee JL, Ha YL, Park GB, Joo ST. 2004. Effects of conjugated linoleic acid on color and lipid oxidation of beef patties during cold storage. Meat Sci 66:771–5.

Jeun-Horng L, Yuan-Hui L, Chun-Chin K. 2002. Effect of dietary fish oil on fatty acid composition, lipid oxidation and sensory property of chicken frankfurters during storage. Meat Sci 60:161–7.

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

Jiménez-Colmenero F, Serrano A, Ayo J, Solas MT, Cofrades S, Carballo J. 2003. Physicochemical and sensory characteristics of restructured beef steak with added walnuts. Meat Sci 65:1391–7.

Jiménez-Colmenero F. 2000. Relevant factors in strategies for fat reduction in meat products. Trends Food Sci Technol 11:56–66.

Jo C, Ho Son J, Bae Son C, Woo Byun M. 2003. Functional properties of raw and cooked pork patties with added irradiated, freeze-dried green tea leaf extract powder during storage at 4°C. Meat Sci 64:13–7.

Johnson IT, Southgate DAT. 1994. Dietary fiber and related substances. In: Edelman J, Miller S, editors. Food safety series. London: Chapman & Hall. p 39–65.

Jonas MS, Beckmann SC. 1998. Functional foods: consumer perceptions in Denmark and England. MAPP working paper. Denmark Aarhus: Aarhus School of Business.

Kaeferstein FK, Clugston GA. 1995. Human health problems related to meat production and consumption. Fleisch Technol 75:889–92.

MacAulay J, Newsome R. 2004. Solving the obesity conundrum. Food Technol 58(6):32–7.

Mansour EH, Khalil AH. 1999. Characteristics of low-fat beefburgers as influenced by various types of wheat fibers. J Sci Food Agric 79:493–8.

Mendoza E, García ML, Casas C, Selgas MD. 2001. Inulin as fat substitute in low fat, dry fermented sausages. Meat Sci 57:387–93.

Modi VK, Mahendrakar NS, Narasimha Rao D, Sachindra NM. 2003. Quality of buffalo meat burger containing legume flours as binders. Meat Sci 66:143–9.

Muguerza E, Ansorena D, Astiasarán I. 2003a. Improvement of nutricional properties of Chorizo de Pamplona by replacement of pork backfat with soy oil. Meat Sci 65:1361–7.

Muguerza E, Ansorena D, Bloukas JG, Astiasarán I. 2003b. Effect of fat level and partial replacement of pork backfat with olive oil on the lipid oxidation and volatile compounds of greek dry fermented sausages. J Food Sci 68(4):1531–6.

Muguerza E, Fista G, Ansorena D, Astiasarán I, Bloukas JG. 2002. Effect of fat level and partial replacement of pork backfat with olive oil on processing and quality characteristics of fermented sausages. Meat Sci 61:397–404.

Muguerza E, Gimeno O, Ansorena D, Bloukas JG, Astiasarán I. 2001. effect of replacing pork backfat with pre-emulsified olive oil on lipid fraction and sensory quality of Chorizo de Pamplona—a tradicional Spanish fermented sausage. Meat Sci 59:251–8.

Pappa IC, Bloukas JG, Arvanitoyannis IS. 2000. Optimization of salt, olive oil and pectin level for low-fat frankfurters produced by replacing pork backfat with olive oil. Meat Sci 56:81–8.

Pascal G, Collet-Ribbing C. 1998. Las perspectives europeas sobre los alimentos funcionales. Institute for Prospective Technolgical Studies: Sevilla, Spain. IPTS Report 24:1–7.

Pietrasik Z, Duda Z. 2000. Effect of fat content and soy protein/carrageenan mix on the quality characteristics of comminuted, scalded sausages. Meat Sci 56:181–8.

Porcella MI, Sánchez G, Vaudagna SR, Zanelli ML, Descalzo AM, Meichtri LH, Gallinger MM, Lasta JA. 2001. Soy protein isolate added to vacuum-packaged chorizos: effect on drip loss, quality characteristics and stability during refrigerated storage. Meat Sci 57:437–43.

Ruusunen M, Vainionpaa J, Poulanne E, Lyly M, Lähteenmäki L, Niemistö M, Ahvenainen R. 2003a. Physical and sensory properties of low-salt phosphate-free frankfurters composed with various ingredients. Meat Sci 63:9–16.

Ruusunen M, Vainionpaa J, Poulanne E, Lyly M, Lähteenmäki L, Niemistö M, Ahvenainen R. 2003b. Effect of sodium citrate, carboxymethyl cellulose and carrageenan levels on quality characteristics of low-salt and low-fat bologna type sausages. Meat Sci 64:371–81.

Sadler MJ. 2004. Meat alternatives - market developments and health benefits. Trends Food Sci Technol 15:250–60.

Schieber A, Stintzing FC, Carle R. 2001. By-products of plant food processing as a source of functional compounds—recent developments. Trends in Food Science and Technology 12:401–13.

Severini C, De Pilli T, Baiano A. 2003. Partial substitution of pork backfat with extra-virgin olive oil in "salami" products: effects on chemical, physical and sensorial quality. Meat Sci 64:323–31.

Steenblock RL, Sebranek JG, Olson DG, Love JA. 2001. The effects of oat fiber on the properties of light bologna and fat-free frankfurters. J Food Sci 66(9):1409–15.

Tang S, Kerry JP, Sheehan D, Joe Bukley D, Morrissey PA. 2001. Antioxidative effect of added tea catechins on susceptibility of cooked red meat, poultry and fish patties to lipid oxidation. Food Res Int 34:651–7.

Vasconcellos JA. 2001. Alimentos funcionales. Conceptos y beneficios para la salud. World Food Sci 1(6):1–19.

Velasco S, Cañeque V, Lauzurica S, Pérez C, Huidobro F. 2004. Effect of different feeds on meta quality and fatty acid composition of lambs fattened at pasture. Meat Sci 66:457–465.

Wood JD, Richardson RI, Nute GR, Fisher AV, Campo MM, Kasapidou PR, Sheard PR, Enser M. 2003. Effects of fatty acids on meat quality: a review. Meat Sci 66:21–32.

Yilmaz I, Simsek O, Isikli M. 2002. Fatty acid composition and quality characteristics of low-fat cooked sausages made with beef and chicken meat, tomato juice and sunflower oil. Meat Sci 62:253–8.

Yilmaz I. 2004. Effects of rye bran addition on fatty acid composition and quality characteristics of low-fat meatballs. Meat Sci 67:245–9.