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FUNCTIONAL RESTRUCTURED MEAT: APPLICATIONS OF INGREDIENTS DERIVED FROM PLANTS

REESTRUCTURADOS CÁRNICOS FUNCIONALES: APLICACIÓN DE INGREDIENTES DERIVADOS DE PLANTAS

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ABSTRACT

Background: Meat is an important source of nutrients. However, in recent years their consumption is associated with chronic-degenerative diseases giving it the perception of "unhealthy food" Given that meat is an affordable source of quality protein; its improvement entails a huge challenge for the industry and science. **Methods**: The search and structured review of the literature in the last ten years in the scientific databases of articles related to the elaboration of restructured meat products with functional ingredients derived from plants. **Objective**: This work presents a general overview, as well as the most representative studies on the elaboration of restructured meat with ingredients from plants considered functional. **Conclusions**: The present review is intended to emphasize the use of plant natural ingredients in the elaboration of functional restructured meat products as an alternative for consumers allowing the inclusion of functional compounds beneficial to human health in their daily diet.

Keywords: functional meat, fiber, antioxidants, fruit juices, food economy.

RESUMEN

Antecedentes: La carne es una fuente importante de nutrientes. Sin embargo, en los últimos años su consumo se asocia a enfermedades crónico-degenerativas dando la percepción de alimento poco saludable. Dado a que es una fuente accesible de proteína de calidad, su mejoramiento implica un enorme desafío para la industria y la ciencia de la carne. **Método**: La revisión estructurada de diversos artículos de investigación encontrados en bases de datos científicas, durante los últimos 10 años, relacionados a la elaboración de reestructurados cárnicos con derivados de plantas considerados *funcionales* **Objetivo**: Este trabajo presenta una revisión general, de los estudios más representativos sobre la elaboración reestructurados cárnicos elaborados con derivados de plantas considerados como funcionales. **Conclusión**: La elaboración de productos reestructurados cárnicos funcionales con la utilización de derivados vegetales, puede considerarse una alternativa para los consumidores a fin de incluir compuestos funcionales beneficiosos para la salud humana en la dieta diaria.

Palabras clave: carne funcional, fibra, antioxidantes, péptidos bioactivos.

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BACKGROUND

Meat is a highly nutritious source of food that provides high-quality nutrients like proteins, minerals and vitamins. Despite the nutrimental content associated with the consumption of meat, particularly of red meat (beef, pork and lamb) (1), it has been linked with coronary heart diseases due the proportion of saturated fatty acids content (2) and the several types of cancer due to the mechanisms that increase the generation of chemical toxins (carcinogens and mutagens) during the processing operations such as curing, smoking, fermentation, heat treatment and storage (1). The use of chemicals for meat preservation especially of synthetic antioxidants, such as butylated hydroxyanisole (BHA), butylated hydroxytoluene (BHT) and tertiary butyl hydroquinone (TBHQ) cause toxicological effects. The concern about the fat consumption has created demand for healthier products by consumers and important challenges for meat industry (3).

The growing understanding of the relationship among diet, specific food ingredients and health is leading to new insights into the effect of food components on physiological function and human health. This awareness has moved consumers to become more health-conscious driving a trend to healthy and nutritious foods with additional functions of health promoting, such as functional meat (4). For considering any food as "functional" there are three basic requirements: 1) derived from a naturally occurring ingredients; 2) consumed as part of daily diet; and 3) involved in regulating specific process for human including delaying aging, preventing the risk of disease and improving the immunological ability (5). The advantage of functional foods is that they can deliver health benefits to the consumer without greatly affecting the diet, as well as looking and tasting like regular foods (6). Nevertheless, apart from nutritional and health concerns, meat consumers also demand for quality products at a moderate price; in meat industry, the performance of restructured products from low value meat pieces and trimmings can enhance their value. In addition, consumers are now more health conscious and the producers are in pressure to develop new healthy products enriched with a variety of non-meat ingredients (7).

Restructured meat products could be an excellent source for functional foods formulations at low price: they are versatile for multiple dishes and they can be made with the high-quality nutrients of meat. In general, the design and development of meat-based functional foods basically seeks to reduce the presence of compounds with negative health implications and increase the presence of beneficial compounds (8) like antioxidant, proteins, fats and fibers of plant based (9-11).

The concept "restructuring" is a partial or complete disassembling of meat and a reforming into the same or different form which implies the binding or holding of small meat pieces together using natural proteins to generate a meat product (12).

These restructured products can be elaborated under diverse conditions. Regularly; salt, alginates and phosphates have been used to bind meat along with heat treatments; also, various enzymes are commercially used for the structural engineering of restructured meat of which microbial transglutaminase (MTG) is a cross-linking enzyme that has taken the leading role (7). Despite restructured meat offer advantages for consumers and meat industry, it represents a huge challenge due to the limitations of restructured meat products like their rapid lipid and protein oxidation, and the modifications on texture and color during storage. These problems were successfully solved with the addition of some Plant Based Derivatives (PBD) considered as a functional in formulation of restructured meat products. The addition of PBD not only improve some technological characteristic of restructured meat, it also helps to consider meat as a functional product with ingredients that promote human healthy. The aim of this study is to review the use of functional PBD in restructured meat products to a have better understanding of their use and benefits.

Plants based derivatives used for restructured functional meat

To obtain functional meat there are different approaches based on animal production practices (genetic and nutritional) and meat transformation systems (restructured process ie). The design of restructured functional meat is a multifactorial process (Figure 1). It not only requires information regard the PDB but also information about: a) meat aspects, specially, the type of cut because these are the primary base to design restructured products, b) quality traits, to include PBD in meat products could change the quality of characteristic, especially those regarding sensory properties (13). The addition of the noni fruit (*Morinda citrifolia*) to beef patties increases the color stability and shelf life of fresh ground beef, however, in taste panelists perceived the patties to have less beef flavor and greater incidence of off-flavors derived from the noni fruit, and c) product specifications: some natural products produce allergies reactions (like nuts or peanuts) and considered the world legislation like Japanese Ministry of Health and Welfare for functional foods as "foods for specified health uses" (FOSHU), or the Europe, Regulation 1924/2006 dictated by European Commission (6).

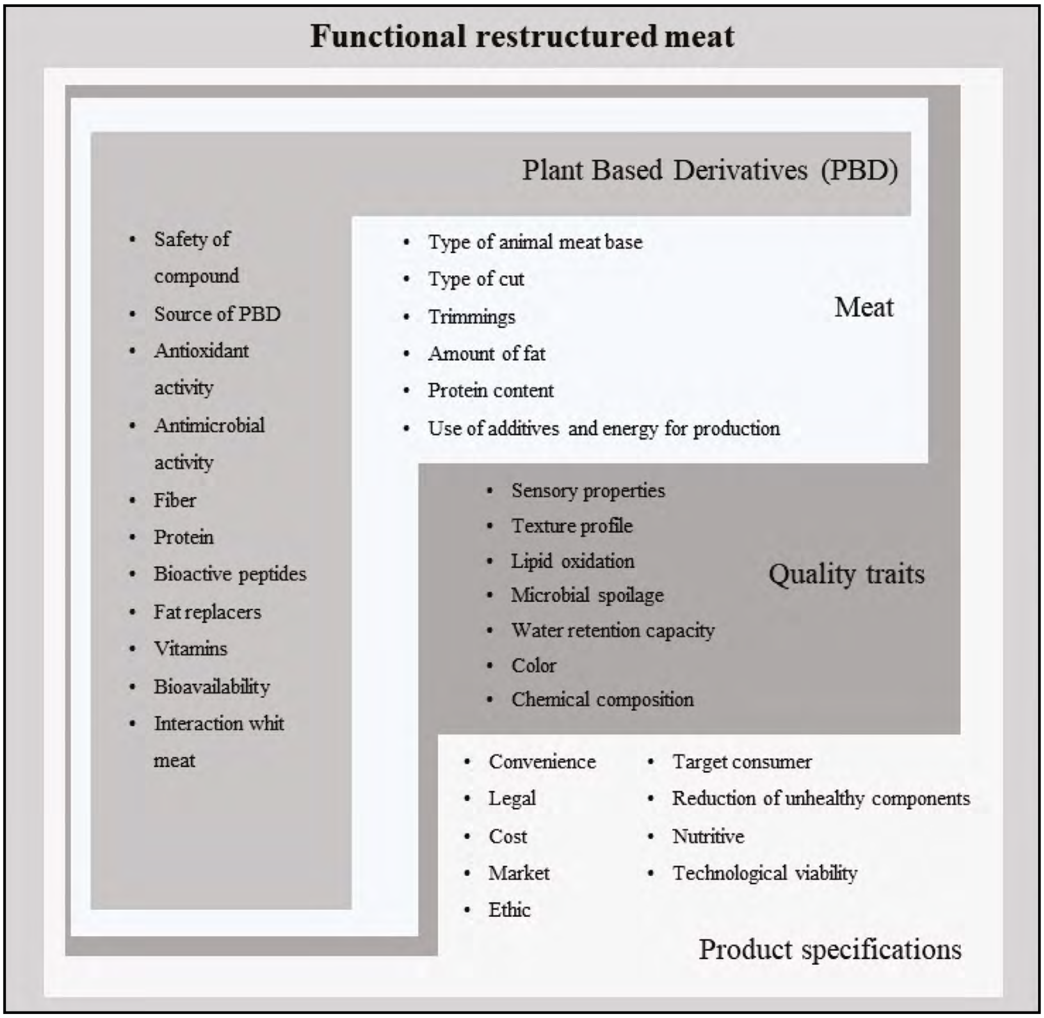

Figure 1. Principal considerations for restructured meat design.

Restructured meat has been widely used to remove, reduce, increase, add and/or replace different bioactive components and to obtain specific meat-based designs with certain attributes that confer health-promoting properties (10). PBD are a generous source to supply man with valuable compounds to preserve and improve the overall quality of meat and its products (6). The PBD used on restructured meat usually are starches, non-starch hydrocolloids, fibers, proteins and natural antioxidants among others (14), however, despite the highly use of starches as additive in meat industry, for this review purpose, only PBD with functional properties were summarized.

Fiber

Finding an agreement among various scientific groups and regulatory agencies on a definition for fiber or most commonly Dietary Fiber (DF) has proven difficult, actually is defined as "The edible parts of plants and analogous carbohydrates that are resistant to digestion and absorption in the human small intestine with complete or partial fermentation in the large intestine. DF includes polysaccharides, oligosaccharides, lignin, and associated plant substances. DF promotes beneficial physiological effects including laxation, and/or blood cholesterol attenuation, and/or blood glucose attenuation" (14). Distinct types of DF have been studied alone or combined with other ingredients for meat formulations, due to their diverse technological properties to generate functional foods (humectants, thickener and stabilizer). Binder in meat is often used as a texture modifying agent, fat/sugar replacement, texture modification gelling agent, texture modifying agent, fat replacer, improves water holding capacity improves water holding capacity, thickener, stabilizer, humectants and extenders (15).

Despite the high quantity of studies where DF are added for technological reasons, DF may be considered functional ingredient since they also provide various potential beneficial physiological effects, including the maintenance of gut health (by facilitating excretion), prevention of carcinogenesis, reduced risk of coronary heart disease (hypocholesterolaemic effects), prevention of diabetes type 2 (ability of the fiber to reduce the glycaemic response) and reduction of obesity (by imparting a sensation of satiety) (16), or contain antioxidant compounds which might diminish the unhealthy compounds and breeding the DF other functional characteristics (17).

Many researches have shown that fiber fortification into meat products at nutritionally significant levels can be accomplished without adverse impact on sensory quality (18) like application of rice bran, rye bran, apple and passion fruit on diverse meat products (19-22). However, the benefit of DF on meat products also has other advantages such as fat replacement and improved oxidative stability when the fiber source is associated with phenolic antioxidants like the study performed by Fernandez-Gines (17) who reported the diminish of unhealthy compounds due to the presence of an antioxidant compound derived from albedo lemon.

Although the variety of DF sources, inulin is considered a functional ingredient not only for their fiber characteristics, but also its function as prebiotic and capacity to inhibit the development of colon cancers in animal models and its excellent property as carbohydrate-based fat substitute (23). The inulin has been probed on meat products with satisfactory results. (24) studied the use of inulin and bovine plasma as a fat replacer, they found a fat reduction of 20-35% and particularly no changes were observed in color, flavor or taste among the samples which is important because the addition of DF generally produces bad changes on the acceptability of meat products. In the research conducted by (25), combinations of both fructo-oligosaccharides (FOS) and inulin, respectively combined with oat bran for prebiotic conservation on meat burgers, had a higher concentration of fibers than the minimal imposed level (3 g of dietary fiber for 100 g of food product) for prebiotic food in all meat samples. (26) proved a paté prepared with inulin gels as fat replacers with a fat content reduced (up to 82%), and decreased (up to 58%) as energy value, the fat reduction and addition of inulin gels decreased hardness and chewiness, but the pâté's appearance, taste and odour, as well as overall quality were very similar to the control elaborated whit full-fat.

In the other hand, a work performed with veal meatballs containing inulin results in lower concentrations of total fat and total trans fatty acids than the control samples. The meatballs with 20% inulin had a better nutrition and quality characteristics has a highest ash, protein, lightness, yellowness and lowest moisture, salt, weight losses and redness. Sensory scores of meatballs with 10, 15 and 20% added inulin were less acceptable due to hardness, low juiciness, and low flavor intensity, the incorporation of inulin at 5% level was found as the optimal in veal meatballs **(**27).

Proteins

In some cases, plant proteins can be considered foreign or contaminant in certain meat products (28), notwithstanding, there is a novel approach for considering bioactive peptides as a functional ingredient in meat products (29). Bioactive peptides are short sequences of amino acids that are inactive within the sequence of the parent protein but have a positive health impact on systems of the body once released (Figure 2). To date, numerous bioactive peptides and hydrolysates are considered to have health benefits (30), as a well their use as replacers for synthetic conserving due to their antioxidant activity capable to delay oxidation reactions (30).

The bioactive compounds could be used as nutraceutical ingredients in meat products but at low levels because some peptides had a biter pronounced taste like those liberated by papain enzyme. Addition of bioactive peptides can be used as an encapsulates or water-in- oil-in-water emulsions (18) and the protection of lipids and proteins from oxidation is possible. Despite the research studies on applied bioactive peptides derived from animal sources (include those derived from meat itself) (31), four our knowledge, the application of bioactive peptides from vegetal sources is a new research area and there are few or no information regarding on meat restructured products.

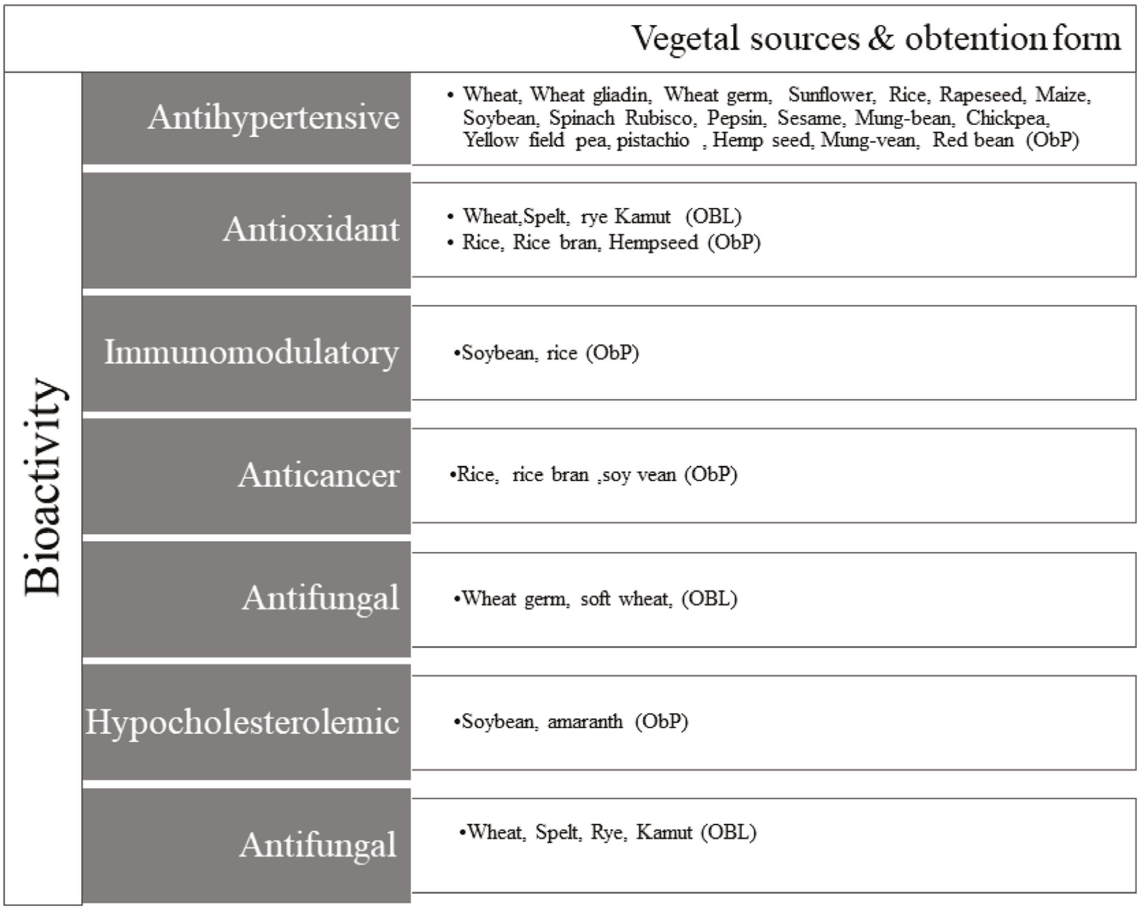

Figure 2. Principal functions and sources of vegetal bioactive peptides, utilized in restructured functional meat products. Adapted from: (32). ObP: obtained by proteases, OBL: Obtained by Lactic acid Bacteria fermentation.

Lipids

Due to the importance of lipids, among functional ingredients these have received most attention, particularly (in quantitative and qualitative terms) with respect to the development of healthier meat products (33). Vegetable oils contain a part of saturated fatty acids and a part of unsaturated fatty acids with isolated double bounds, particularly in *cis*-configuration. A particularly important group of compounds within unsaturated fatty acids are the long-chain (C:16 to C:20), polyunsaturated fatty acids (PUFAs), which are essential for normal growth and development having an important role in the prevention and treatment of coronary artery disease, hypertension, diabetes, arthritis, other inflammatory and autoimmune disorders, cancer, type 2 diabetes, renal disease, rheumatoid arthritis, ulcerative colitis, Crohn disease and chronic obstructive pulmonary disease (34).

Meat it is low in their content of PUFAs, the inner fat content indeed had a low effect on meat product characteristics like flavour, mouthfeel, juiciness, and texture and it's difficult to be reduced or modified only whit the replacement or the diminish of their fat content (33). Lipid reformulation by replacing a portion of the animal fat by fat substitutes containing PUFAs-rich oils may provide healthier characteristics to the meat product. Due to their low SFA (saturated fatty acids) content and healthy n−6/n−3 ratio, vegetal oils are an interesting alternative to improve the nutritional quality of meat products. However, the use of liquid oils rich in n−3 PUFA in meat products may impair important technological and sensory attributes as well as reducing the shelf life of the product due to the increase of lipid oxidation (35).

To include healthier vegetal lipids on meat products there are different approaches for liquid oils or solids (including interesterified oils) as in encapsulated or pre-emulsified forms or as part of plant ingredients specially on raw meat products (33) (Figure 3). However, it is important to consider the short life of the PUFAs due to a major susceptibility to be damaged by oxidation reactions, indeed, a better way to solve that problem is through the inclusion of lipid sources that can include a bioactive compound like antioxidants. It has been recommended the use of olive oil, hydroxytyrosol and walnut not only for their high content of PUFAs, but also because these contain important phenolic compounds capable which diminish or slow down the oxidation process (36).

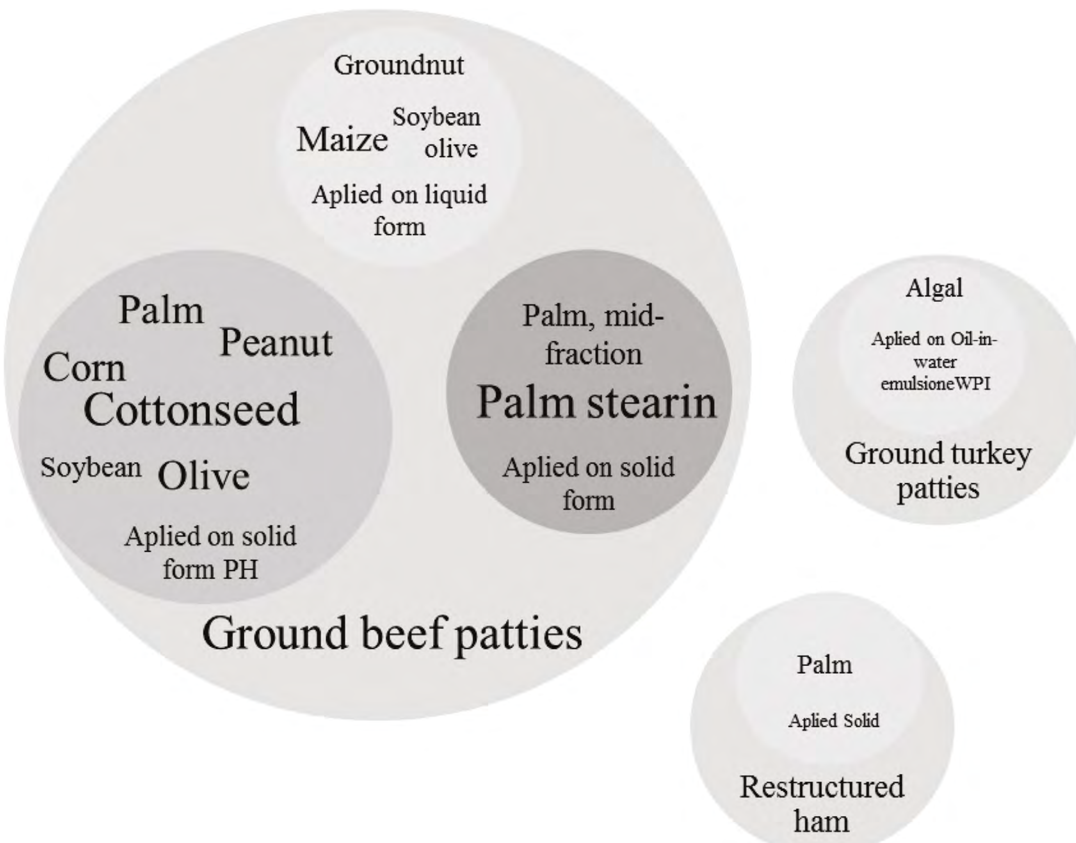

Figure 3. Principal vegetal sources of lipids utilized in restructured functional meat products. Adapted from (33). PH: partially hydrogenated; WPI, whey protein isolate.

Despite the multiple technological issues, the oil addition on meat products has been proved successfully. Kuhnle and Cheng (2017) (37) examined the impact of using vegetable oil as fat replacement on heterocyclic amines (HCAs) formation in meat product with 40% fat replacement by olive oil, sunflower oil or grape seed oil, respectively, they found that control patties contained the highest amount of HCAs, grape seed oil achieved the highest inhibition capacity compared with sunflower oil and olive oil, they conclude that the fat replacement with sunflower oil, olive oil or grape seed oil in pork patties could reduce the formation of HCAs without compromising the eating quality. Heck and coworkers on 2017 (35) studied the effect of the lipid reformulation in beef burgers made by replacing 50% of the fat component by microparticles containing chia (CO) and linseed (LO) oils obtained by external ionic gelation, there were no changes in hardness and improved important technological properties, such as cooking loss and fat retention. In addition, the reformulated burgers led to healthier PUFA/SFA and n−6/n−3 ratios and lower atherogenicity and thrombogenicity indices with no effect on the sensory quality.

Other common source of oil as a fat replacer is palm oil. Mbougueng *et al.,* (2017) (38) tested the inclusion of palm oil at 5, 10, 20, 30, 40 and 50% on the physicochemical and sensory properties of beef liver patty and a control with pork fat (30%), they found that physicochemical analysis of raw and cooked samples showed improvement of emulsion stability, water binding capacity, technological yield and hardness of patties substituted with lower proportions of deodorized bleached palm oil and better sensory attributes mainly on texture, homogeneity (colour and aspect), odour and meltiness of the patties.

Among vegetal oils, olive is the one that has received most attention, chiefly as a source of PUFAs and containing antioxidant substances like oleic acid, phenolics, squalene and several other compounds. Several studies demonstrated that the partial replacement of animal fat with olive oil aids in health benefits (39). In example, the effect of adding an olive waste extract (100, 200 or 400 mg gallic acid equivalents/kg muscle), as a possible natural polyphenol-rich antioxidant on the stability of lamb meat patties enriched with omega-3 fatty acids, and stored in high-oxygen modified atmosphere packs for up to 9 days at 4°C; shows a delay on meat discoloration, lipid oxidation ($p \leq 0.001$) and protein carbonylation ($p \leq 0.001$). The addition of oil waste resulted in acceptable lamb meat patties and the author recommended this practice as a good strategy to follow an eco-friendlier olive oil production chain (40).

The olive oil is not the only source of antioxidant compounds that can successfully turn regular meat to functional meat, besides bioactive peptides, the exogenous antioxidants derived from food and medicinal plants mainly rich in polyphenols (phenolic acids, flavonoids, anthocyanins, lignans and stilbenes), carotenoids (xanthophylls and carotenes) and vitamins (vitamin E and C) (41) are an excellent and the most common way for meat preservation without sintetic additives.

Natural antioxidants

In the present days, special attention has been paid to many plants as the most common source of antioxidants for preservation as a well nutritional quality improvement turning meat in to "functional meat". Plants are persistently the generous source to supply man with valuable bioactive substances like natural antioxidants to preserve and improve the overall quality of meat and meat products (42).

The antioxidant compounds are greatly investigated for their healthy properties especially those related to oxidative stress which is recognized as pro-oxidant/antioxidant imbalance situation, which can be induced by the production of reactive oxygen species (ROS). Those are strong oxidizers of important molecules like lipids, proteins and nucleic acids, causing damage that eventually leads to DNA damage free radicals and enhanced cellular damages, indeed oxidative stress is a common factor in different frequent pathologies, such as cardiovascular diseases, neurodegenerative disorders, and cancers critical pathophysiological mechanism (43).

Natural antioxidants maintain the delicate oxidation–reduction, antioxidants will react with radical and non-radical species to initiate the defense mechanisms for the protection of both intracellular and extracellular components. The plant kingdom is the most abundant source of antioxidants, which are richly presented in spices (seeds), herbs, and essential oils used in meat products for organoleptic purposes. Certain fruits, tree leaves and vegetables are also reliable sources of antioxidants and as other phytochemicals (1).

Natural antioxidants that have been studied in meat for product quality preservation, may also be regarded as nutraceutical ingredients or supplements for health promotion. Indeed, plant-derived antioxidants provide meat processors with the flexibility to develop novel products with enhanced nutritional value and health benefits, an improved shelf-life, and an attractive overall quality profile (1). The use of natural antioxidant compounds includes a vast number of different plant parts (44), the variety of sources, compounds, extraction methods and application on restructured meat are extensively studied with significant results in terms of preservation, flavor and another meat quality characteristics.

Table 1. Antioxidants used in restructured functional meat products.

Source	Main active compound	Mode of action	Meat product	Ref
Pomegranate peel extract	hyrolysable tannins, anthocyanins and flavonoid	Radical scavenger	Beef meatballs	1
Red grapes, gooseberry and tomato	polyphenolic compounds	Radical scavenger	Restructured chicken block	2
rosemary–tocopherol	tocopherol and volatile acid compounds	protects highly oxidizable polyunsaturated fatty acids	Restructured irradiated pork loins.	3
Walnuts	high-biological-value proteins, vegetable fibre, polyunsaturated (linoleic and linolenic) fatty acids (especially g-tocopherol), and other antioxidants (phytosterols and polyphenols),	Radical scavenger	Restructured beef steak	4
Rosemary extract, chitosan and carnosine	phenolic diterpenes such as carnosic acid, carnosol, rosmanol, rosmariquinone and rosmaridipheno	act as metal chelators and singlet oxygen quenchers	Beef patties w	5
Noni (morinda citrifolia)	antraquinones	Radical scavenger	Beef burgers	6
Grape antioxidant dietary fiber (GADF)	Dietary fiber and phenolics antioxidants such as pehnolics acids, anthocyanidins, proanthocyanidins, catechins and other flavonoides is	Radical scavenger	Chicken breast hamburger	7
Olive waste extract	tyrosol related compounds and derivatives of benzoic and cinnamic acids	Radical scavenger act as metal chelators and singlet oxygen quenchers	Lamb meat patties	8
Aloe vera	Anthraquinone, phenolic compounds	Radical scavenger	Goat meat nuggets	9

1:(45); 2:(46); 3:(47); 4:(48), 5:(49), 6:(13); 7:(50); 8:(40), 9:(51).

Antioxidants are added to restructured meat products to prevent lipid oxidation, delay the development of off-flavors, and improve the color stability in some cases the vegetal sources also improve the flavor of the product.

CONCLUSIONS

Meat products are not a traditional matrix which include functional ingredients, their incorporation imply significant technological challenges and multidisciplinary approaches as they were a mentioned in this review, however, restructured meat might be a great option for the inclusion of plant based derivatives functional ingredients capable to achieve the needs of increasingly conscious consumers about a healthy way of life _Plant based derivatives not only improve some technological characteristic of restructured meat, it also could help to a diminish the perception of meat products as a unhealthy foods, bringing to the consumers, the opportunity to incorporate functional compounds beneficial for human health in their daily diet

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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