Chapter 9

Meat Product Reformulation: Nutritional Benefits and Effects on Human Health

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http://dx.doi.org/10.5772/intechopen.69118

Abstract

This chapter aims to present the current state of the art in the field of meat product reformulation with respect to issues concerning the nutritional improvement and overall health benefits of such products. Our research team has recently finalised a national research project concerning this topic, and we feel that other food scientists could benefit from the theoretical and practical knowledge gathered during this time. The chapter will be divided into four subchapters. The first subsection will present the main targets of meat reformulation, such as lipid or protein profile modification, the use of bioactive compounds as additives, etc. The second subsection will discuss the bioavailability and bioaccessibility of carotenoids, phenolic compounds and other bioactive compounds, presenting these parameters from a nutraceutical perspective. The last subsections will include reported consumer attitudes. In this work, we will present data that could aid scientists in the field of food science to better grasp notions concerning consumer benefit, such as bioavailability, not only of a specific bioactive compound but also as part of a complex food matrix.

Keywords: reformulation, bioactive compounds, bioavailability, bioaccessibility, nutrition, human health

1. Introduction

Meat and meat products are a class of food products that are commonly included in human diet, due to the intake of good quality nutrients, diverse forms of presentation and highly appreciated sensorial characteristics. On the other hand, a number of studies have been published on the negative impact of meat consumption upon health. In 2007, a report of the World Cancer Research

Fund described a connection between the intake of processed red meat and the risk of colorectal cancer. Although this connection has not been fully clarified yet, it is presumed that cancer precursors could be excess fat, protein and iron, heat-processing compounds (heterocyclic amines) and various substances added during the technological process (sodium chloride and nitrates). The same report recommended the intake of less than 500 g cooked red meat per week [1].

Similarly, the intake of processed red meat was associated to an increased occurrence of cardiovascular disease and diabetes mellitus, but the triggering mechanisms of these conditions have yet to be fully understood. In order to meet the consumers' demands, as consumers have become increasingly concerned with the ingredients of the food products purchased, the present research in the field approaches the topic of *reformulating the meat products*, impacting upon obtaining functional products. The technological strategies used to reformulate meat products and obtain functional products are based on improving the fat content, incorporating proteins of vegetable origin, prebiotics and vegetable fibres: increasing the mineral content, including vitamins, antioxidants and vegetable compounds with a functional role [2], and reducing the exogenous compounds harmful to health.

2. Meat product reformulation

Reformulated meat products have been created to help consumers, who are constantly requiring nutritionally improved meat products, that is, with a lower content of fats, cholesterol, sodium chloride and nitrites, as well as a higher content of compounds beneficial to human health. The influence of the meat product composition on human health has long been well known, but the scientific foundation of the physiological role of bioactive compounds in modulating specific functions in the body is not yet fully understood.

Reformulating meat products may be achieved in the following manners [3]:

1. Increasing the concentration of a meat product (macronutrient or micronutrient) up to a desired level
2. Adding a component normally not existing in meat
3. Partial or total replacement of a macronutrient which may trigger nutritional deficiencies with a nutritionally beneficial component
4. Reducing the nutritionally harmful components
5. Improving component bioavailability or stability
6. Combinations of the above

2.1. Reduction of cholesterol, sodium, nitrite and phosphate contents

Depending on its concentration, circulation or accumulation in the human body, cholesterol may be desired or not in diet. Due to the association of cholesterol-rich diet with coronary heart disease, in the most situations, food containing the high level of cholesterol is avoided.

http://dx.doi.org/10.5772/intechopen.69118

Meat (especially red meat) and meat products are among this food. On the other hand, meat and meat products provide beneficial compound for the human body: high-quality proteins, high bioavailable iron, vitamin B12, zinc and selenium. In this context, there have been developed some possibilities to reduce the level of cholesterol in meat and meat products: lecithin treatment; short-path and path molecular distillation; supercritical carbon dioxide extraction; extraction by saponin, using cholesterol oxidase; etc. Some of these methods are costly, non-selective and not enough studied. The addition of cholesterol-lowering compounds, such as phytosterols and soy proteins, is more suitable for this purpose [4].

Sodium chloride (currently named *salt*) is widely used in meat products due to a series of technological benefits (increases the proteins' water-binding capacity, improves texture and shelf life). Because of the negative health impact of sodium consumption (high blood pressure) [5], several strategies for lowering salt content in meat products have been reported [6]: the use of salt substitutes (potassium chloride, magnesium chloride, calcium chloride, calcium ascorbate [7]), the use of flavour enhancers (monosodium glutamate or yeast extract) and the use of novel processing technologies (high-pressure processing and power ultrasound). These strategies have their limitations and may be combined.

Nitrite has numerous functions in meat products [8, 9]: prevents lipid oxidation, gives products the specific colour and provides antimicrobial activity. Their reduction implies the addition of other antioxidants (either natural or artificial), colourants or preservatives. In the manufacture of meat products, phosphates are used in order to increase the water-holding capacity, leading to a good texture and poor cooking loss. Due to their implication in setting of chronic diseases like diabetes, obesity or cardiovascular disease, phosphates are tending to be replaced by sodium citrate, carageenans or proteins of different origins (porcine blood, soybean and milk) [10, 11].

2.2. Enrichment of minerals and improvement of amino acid quality

Meat is known as an essential source of macro- and micro-nutrients indispensable to human diet as protein, fat, minerals and vitamins. While the minerals can be achieved only by exogenous sources in the body, the enrichment of meat products with minerals is important. Several studies demonstrated the beneficial cumulated effects of low fat or low salt and minerals (as potassium, calcium and magnesium) added in meat matrix on the plasma cholesterol in humans [12]. Triki et al. [13] had reformulated sausages by partially replacing the NaCl content by adding a mixture of KCl, $CaCl_2$ and $MgCl_2$. They have found that the product mineral profile was improved providing 10–15% of the recommended daily allowance (RDA) of potassium, 8–10% of the calcium RDA and 10–20% of the magnesium RDA. One of the most essential trace minerals is selenium being involved in regulating various physiological functions. In human metabolism, selenium deficiency is associated with decreased immune function resulting in increased susceptibility to some chronically diseases [14, 15]. The enrichment of meat with selenium could be reached by two ways: adding selenium in different meat matrices or by feeding the animals with fortified food [16]. Essential amino acids are integral part of meat and meat products. The umami taste could be intensified by the presence of sweet amino acids, such as glycine, alanine and serine [17]. A large increase in free amino acid quality occurs during long maturation and the curing of meat products. Other researchers

have found that amounts of hydrophobic amino acids released during the fermentation or maturation process were significantly higher than other amino acids.

2.3. Incorporation of some healthy ingredients, reduction of fat content and improvement of fatty acid content

Within of the framework of the Nutritional Optimizing of Some Meat Products with Valorization of Plants Riched in Bioactive Compounds (OPTIMEAT) project, the P2 Partner ('Dunarea de Jos' University of Galati) has investigated two possibilities for reformulating meat products:

(a) Lipid reformulation by adding a vegetable ingredient made up of nuts and nut oil, sea buckthorn oil or sunflower seed oil

(b) Proteic reformulation by adding a vegetable ingredient made up of soy proteic isolate and juice of red beetroot or dry tomatoes

The main components used in the project are presented below.

2.3.1. Walnuts

Walnuts (*Juglans regia* L.) are common all over the world. Known under various names, such as Persian nut, white nut, English nut or common nut, it is used to be cultivated in the Eastern Balkans and the Western Himalayan range, but at present it can be found all over Europe. Worldwide, there are many types of nuts, such as almonds, peanuts, earth nuts, cashew nuts, macadamia nuts, pistachios and pecan nuts.

It may be said that adding walnuts has positive implications in the creamy consistency of frankfurters as compared to traditional products where pork fat has a tougher consistency. There are also alterations in the fat-protein-fibre interactions supporting the gel formation process, which is essential in frankfurter manufacture. Thus, adding walnuts increases product consistency and at the same time the nutritional value of the product, becoming a viable alternative for this product [18–23]. The nutritional profile of products in which animal fat was replaced by walnuts is by far healthier and richer than that of the traditional products. By adding walnuts to products, an increase in the nutritional value and the quantity of biologically active compounds beneficial to human health can be observed. It may be observed that the number of studies in the field is relatively low, and the existing ones mention the need for further research, more detailed and on other products, and also in comparison to other products available on the market. Also, it is recommendable to study the stability and shelf life of these new products. The results of the academic studies are very valuable and recommend the use of walnuts in optimising the nutritional characteristics in meat products.

2.3.2. Tomatoes

Several studies using tomatoes and their derivatives were reported in improving meat products. Deda et al. [24] analysed the influence of adding tomato paste in pork frankfurters,

reaching the conclusion that it enhances the colour and attractiveness of the final product. Similar results were obtained by Eyiler and Oztan [25] for adding tomato powder. Calvo et al. [26] studied the implications of adding tomato skins to raw-dried sausages, while Savadkoohi et al. [27] added extracts from tomato skins and seeds to frankfurters and beef ham. All these studies evinced the improved colour of the meat products obtained, as well as the improved texture and water-bonding ability. These effects are due to the high content of lycopene and beta carotene, as well as soluble fibres contained in tomatoes.

The bioavailability of lycopene depends on the following factors: the components of the food matrix, the physical state of lycopene, the size of particles before and after chewing, the intensity of digestive processes and the presence of fibres [28, 29]. Red tomatoes contain 95% lycopene as a *trans*-isomer (the most stable form of lycopene) [30, 31].

In addition to the beneficial effects on human health, tomato-derived products may contribute to reducing the added synthetic colourings in meat products, such as hamburgers, fresh sausages, salami or frankfurters, at the same time improving the nutritional profile by the content of bioactive components [24, 25, 32–34]. Certain synthetic colourings are considered responsible for allergic reactions or harmful side effects, and that is why consumers associate the presence of natural colourings with healthy and qualitative food products.

2.3.3. Soy protein isolate

Proteins from plants are used in meat industry for technological reasons, such as cutting costs and nutritional reasons and lately their health-promoting properties [39]. Soy beans contain the average 40% of protein and 20% of fat. By removing fat at low temperatures, the soy protein isolate is obtained, which is highly used in food industry. The predominant proteins in soy protein isolate are β-conglycinin and glycine. Their structure was thoroughly investigated by various methods, leading to the conclusion that glycine contains a multitude of disulphide groups, which is why its ability of foaming and emulsification is slow, as compared to β-conglicynin [35].

Proteic ingredients are the main vegetable component used in manufacturing meat products, for technological purposes—cutting costs—as well as for nutritional benefits, reducing the cholesterol level, increasing the proteic components and improving the amino acid profile. In meat industry, soy proteins are used in obtaining meat pasta to increase emulsion stability by forming a protein matrix that includes water and fat droplets [36]. Specialised literature in the field shows that adding soy proteins in products containing meat pasta has beneficial effects: Matulis et al. [37] reported a less rubbery texture of frankfurters with a low-fat content and Rahardjo et al. [38] reported lower cooking losses and improved texture of pork sausages. Das et al. [39] analysed the effects of adding soy (as pasta or textured granules) on the quality and storability of the nugget-type products made of goat meat. The findings of the study were that adding soy improves the appearance, texture and water-retaining capacity while slowing down fat oxidation during frozen storage. The data published by Youssef and Barbut [40] show that using soy proteins in obtaining meat paste improves the water-bonding ability, emulsion stability, appearance and texture while decreasing thermal treatment losses. The authors mentioned above analysed the microstructure of the samples obtained, concluding that adding soy proteins lowers the aggregation degree of meat proteins and reduces the size of fat droplets.

Although the influence of the soy protein addition on meat products has been thoroughly studied, their use is limited by the negative influence on taste, smell and colour. Under these circumstances studies are needed regarding the percentage of soy protein isolate that may be added to meat products in order to improve their quality.

2.3.4. Red beetroot juice

Red beetroot juice contains important quantities of antioxidants [41] together with micronutrients such as potassium, magnesium, folic acid, iron, zinc, calcium, phosphorus, vitamin B_6, soluble fibres and pigments (betalains—compounds of betacyanins and betaxanthins). Specialists have been increasingly interested in red beetroot juice due to the content of phenolic compounds [42, 43]. Red beetroot juice mainly contains pigments called betalains, a class of compounds derived from betalamic acid, mainly composed of betacyanin and betaxanthin. In addition to these, red beetroot juice also contains small amounts of gallic, syringic and caffeic acid, as well as flavonoids [44]. Betalains are used in food industry as natural colourings, but a series of health benefits were also found, antioxidant and anti-inflammatory [45, 46], inhibiting lipid peroxidation [47] and increased resistance to lipoprotein oxidation in low density [48].

2.3.5. Vegetable oils

Vegetable oils play an important role in the human diet and are an important energy source. The main constituents of oils are fatty acids, classified as saturated fatty acids (SFA), monounsaturated fatty acids (MUFA) and polyunsaturated fatty acids (PUFA). Polyunsaturated fatty acids determine the regulation at an optimum level of lipids, mainly low density lipid (LDL) cholesterol in the human body [49–51]. **Table 1** shows the fatty acid percentage for oils expressed from sunflower seeds, soy, palm and walnuts.

The partial or total replacement of animal fat in meat products by vegetable oils may be seen as an efficient strategy of nutritional improvement and a means of increasing oxidative stability.

Fatty acids (%)	Sunflower seed oil	Soy oil	Palm oil	Walnut oil
Saturated fatty acids	8.51 ± 1.91	18.26 ± 0.67	46.34 ± 0.40	9.18 ± 1.09
Monounsaturated fatty acids	45.5 ± 16.89	23.28 ± 1.99	41.46 ± 0.56	23.22 ± 2.87
Polyunsaturated fatty acids	46.10 ± 14.92	57.86 ± 1.20	11.84 ± 0.92	63.45 ± 4.66

Table 1. The content of fatty acids for certain types of vegetable oils.

3. Bioavailability and bioaccessibility of bioactive compounds

In pharmacology, bioavailability is defined as the ratio between the amount of active substance and the speed at which it is yielded and absorbed into the body, then reaches its point

of action and manifests its biological effect. By definition, if the medicine is intravenuously administered, its bioavailability is 100%.

As far as food supplements are concerned, since their administration is most often than not oral, the bioavailability is the ratio between the amount of ingested substance and the amount of the absorbed substance [52]. The nutrients existing in food are not absorbed and used by the body in their entirety. Among the factors responsible for this phenomenon, there are a number of nutrient-related factors (chemical formula, the presence of inhibitors or enhancers, the possibility of interacting with other components) and a number of factors related to the organism using that nutrient (duration of intake, volume of enzymatic secretion, activity of intestinal microflora, state of health, eating style, etc.) [53].

Fat-soluble vitamins (e.g. A, D and E) as well as the ω-3 fatty acids, carotenoids, conjugated linoleic acid (CLA) or curcumin are micronutrients with a hydrophobic behaviour which may play a potential functional role when included in the diet or a food product. Many studies showed that due to the hydrophobic behaviour of these micronutrients, bioavailability is slow or variable [54]. The factors contributing to decreasing bioavailability are grouped into three categories – bioaccessibility, absorption and transformation. Bioavailability refers to the low release into the food matrix, low solubilisation in the gastrointestinal fluids as well as interaction with other insoluble components. Deficient absorption is due to the transportation through the stomach membrane or inhibiting active transporters. Transformation refers to the multiple chemical or metabolic processes in which micronutrients may participate.

Bioactive compounds have various characteristics such as structure and molecular weight, polarity and physical state. They may be introduced directly in a food matrix or indirectly by means of a transportation system. The transportation system focuses on maintaining or improving the bioavailability of the bioactive components and has to possess the following characteristics: protection against chemical or biological spoilage (especially for oxidation and hydrolysis), control of the release of the bioactive component (depending on pH, temperature and other factors) as well as the compatibility between the bioactive component and other parameters of the food matrix [55]. The bioavailability of bioactive compounds is generally low and depends on the components of food matrix. Some processes like ingestion, diffusion, solubilisation, movement across intern membrane and enters in the lymphatic system and circulation affect the bioavailability of bioactive compounds.

4. Effects on human health

The bioactive compounds from the selected sources (described in Subchapter 1.3) have some benefits to human health:

- ω-3 Fatty acids (from walnuts)—anti-inflammatory activity, reduces the risk of cardiovascular disease [56].
- Sterols and stanols (from nuts and vegetable oils)—reduce the total cholesterol level, protection against certain types of cancer, anti-inflammatory activity and improve blood pressure [41, 57, 58].

- Lycopene (from tomatoes)—antioxidant, reduces the risk of cardiovascular disease and protection against certain types of cancer [59, 60].
- Isoflavones (from soy proteic concentrate)—reduce the risk of cardiovascular disease [61].

Nut consumption as a trend is on the increase, especially due to the major nutritional components (proteins, unsaturated fatty acids and fibres), as well as micronutrients (sterols, vitamins, minerals, fatty acids and phenolic compounds) [61–63] and antioxidants [64]. As expected, the consumption of nuts is on the increase owing to their antioxidant properties, mainly responsible for the lowering of LDL cholesterol and associated triglycerides, leading to better results than traditional low-calorie diets, in which the consumption of oils or carbohydrates is replaced by nuts. As the consumption of nuts by Mediterranean population is higher as compared to other areas, the mortality rate caused by heart disease or cancer is low [65].

Walnuts are well known for their nutritional value and the high content of bioactive compounds, such as antioxidants, vitamins, essential amino acids and minerals [66, 67]. It is a common knowledge that free radicals are the main factors causing human illnesses, with implications in the pathology of cancer, atherosclerosis or inflammatory disease [68], and that is why regular intake of nuts and thus of antioxidants is essential. *J. regia* Linn may be used in traditional medicine in preventing or treating helminths, diarrhoea, sinus ailments, gastritis, arthritis, asthma, eczema, dermatitis and the various endocrine diseases, such as diabetes, anorexia, thyroid problems, infectious diseases and cancer. Walnuts are also well known for their rich content of unsaturated fatty acids, vitamin E, fibres, magnesium and potassium [69]. As compared to other nut types (macadamia nuts, pistachios, almonds, cashew nuts, earth nuts, pecans, etc.), which mainly contain monounsaturated fatty acids (MUFA), walnuts are rich in omega-6 and omega-3 polyunsaturated fatty acids (PUFA), which play an essential role in daily diet [70].

These properties qualify walnuts as unique in each consumer's diet. Many studies showed that walnut intake may protect the human body against cardiovascular disease [71] and work as blood pressure regulator by their content of magnesium and potassium, respectively. Replacing saturated fats in daily diet with other mono- or polyunsaturated fatty acids (MUFA or PUFA) decreases the concentration of LDL cholesterol in the plasmatic liquid. The chemical and mineral components may differ according to the variety of genotype conditions, ecological, technical and cultural conditions, climate conditions.

Walnuts are tremendously beneficial to the human body because of their chemical composition; they are also a rich source of fatty acids (mainly the linoleic acid, followed by the oleic, linolenic, palmitic and stearic acids) [70, 72] and tocopherols [70, 73]. In addition, they contain other components beneficial to human health, such as proteins, vegetable fibres, sterols [70], melatonin [74], folates, tannins and polyphenols [75].

Walnuts were selected as potential functional component in reformulating meat products due to the composition of the lipid fractions, especially ω-3 and ω-6 acids and ϒ-tocopherol. Numerous studies [76–79] show that reformulating meat products by adding walnuts in various ratios leads to reducing the risk of cardiovascular disease. Although the action mechanism is not yet fully understood, this effect is due to the high content of lipids (62–68% of the dry substance) and the high ratio of monounsaturated (MUFA) and polyunsaturated fatty acids (PUFA).

Selecting tomatoes as a source of bioactive compounds was based on lycopene, the main pigment in the carotenoid class contained by tomatoes. This carotenoid was studied by many researchers, who found proof in favour of its antioxidant and cancer-preventing properties [80–84]. Together with lycopene, tomatoes are an important source of vitamins A and C, as well as a high content of carotenoids. The role of these antioxidants is to neutralise free radicals and to prevent the decay of cells and membranes, swelling and the occurrence of diseases like atherosclerosis, asthma, diabetes and cancer [85]. Tomatoes also contain high amounts of potassium, niacin, vitamin B_6, folates and riboflavin.

Soy protein isolate has a series of nutritional benefits due to the lower energy value and cholesterol content (when used as fat replacements), the higher protein content, the balanced amino acid profile and the incorporated bioactive compounds [86, 87]. Certain vegetable proteins (sunflower, walnuts) were used in meat systems to balance the lysine/arginine ratio [88]. Soy proteins have been focused on by meat specialists for numerous reasons, such as they ensure a balance in amino acid composition, contain beneficial bioactive components decreasing the cholesterol level in the bloodstream and reduce the risk of cardiovascular disease, and have excellent technological properties like jellification, emulsification and the ability to retain water and fats [35, 89]. Soy proteins are well known for their preventative and therapeutic effect in heart disease, cancer and osteoporosis [90]. Clinical studies on the bioavailability of the soy isoflavone forms (such as food supplements, additives or soy food products) were performed in various geographical areas [91, 92]. However, it may be stated that data are inconclusive for a definite conclusion because of the different dietary habits of the individuals included in the studies, the composition of isoflavones and the amount and quality of the meals under study.

The studies carried out by Wootton-Beard and Ryan [93] showed that red beetroot juice is an important source of antioxidants and polyphenols, which were quantified by various biochemical methods before and after in vitro digestion. McDougall and Stewart [94] proved that polyphenols inhibit α-glycosidase resulting in the stimulation of insulin secretion, thus reducing the absorption of glucose into the bloodstream. Polyphenols increase the glutathione level and the level of antioxidant enzymes (glutathione peroxidase, catalase and superoxide dismutase), being capable of reducing the oxidative stress which is the cause of dysfunctions in the case of cardiovascular disease, diabetes and autoimmune diseases. Being natural products, polyphenols may act on various paths in order to prevent chronic inflammation and are more efficient than synthetically obtained anti-inflammatory medication [95].

Many types of vegetable oils are considered as food products with multiple benefits to human health. Especially, cold-expressed oils are a great source of bioactive lipids, phenolic compounds with an antioxidant role, which may contribute to improving human health [96]. Antioxidants play an important role in maintaining the stability of vegetable oils and reduce oxidative stress in vivo.

5. Consumer attitudes to food reformulation

Meat and meat products many times are comprehended by the consumers like unhealthy. A chance for meat industry to change this perception may be represented by functional or

reformulated meat products [1]. To answer the consumers' needs, the reformulated meat products have been developed. According to Jiménez-Colmenero et al. [88], the consumers may approve the reformulated products if they are promoted like 'healthier' products. To satisfy these needs, the meat industry is encouraged to make new meat products. However, it is a provocation to convince the consumers [97] (as well as the media, nutritionists and legislative authorities) that meat is a suitable carrier for functional ingredients [1, 98, 99]. It is significant to present to the consumer that reformulated meat products can be performed in a manner which will meet all the relevant qualities which consumers look for in traditional meat products [91].

6. Conclusions

Functional foods represent a good opportunity for the meat industry, in order to improve the quality of meat, and create meat products with health beneficial properties. Meat and meat products are excellent foods for delivering bioactive compounds without changing dietary habits. Some bioactive compounds from fruits and vegetables (walnuts, tomatoes, soy protein isolate, red beetroot juice and vegetable oils) appear to play an important role in the prevention of specific diseases like cardiovascular diseases, cancers and diabetes mellitus. These compounds are able to reduce the oxidative stress, which has been associated to the occurrence of chronic diseases, and maintain the health. Nowadays, the consumers demand natural and healthy food products, including meat products, with better nutritional properties. Promoting health through nutrition is an important objective of nutrition and public health programmes in a large number of European countries.

Acknowledgements

This work was supported by the CNCSIS-UEFISCDI Romania as National Project II No. 115/2012—Nutritional Optimizing of Some Meat Products with Valorization of Plants Riched in Bioactive Compounds (OPTIMEAT).

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