Review article

Natural preservatives in meat products

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Abstract: *The use of preservatives in industrial food production is now common practice. However, there is growing concern among consumers over the harmful effects of common chemical preservatives. As a result, there is increased demand for food that that has undergone little or no processing. In recent years, there has therefore been great interest in finding alternatives to chemical preservatives for use in the meat industry, in the form of natural ingredients. Possible solutions include the use of plant extracts, essential oils or antimicrobial peptides. This paper provides a review of research on the replacement of artificial preservatives in meat products with traditional chemical compounds of natural origin.*

Keywords: *natural preservatives, essential oils, plant extract, antimicrobial peptides*

Introduction

In recent years, there has been an increase in consumer awareness not only of the calorific value of food, but also of the content of individual nutrients and components, together with their health benefits and risks [1]. The adverse effects of chemical preservatives currently in use are leading producers to look for new alternatives in food technology. One such possibility is the use of plants, in the form of aqueous extracts or essential oils rich in biologically active compounds. Other options are the return to traditional production methods, or using products of animal or plant origin that contain antimicrobial peptides[8].

In developed countries, the development of diseases of civilization caused by lifestyle and excessive consumption is encouraging many people to turn to unprocessed, traditional and regional foods, which are perceived to be more wholesome. A healthy lifestyle involves not only different physical activity habits, but also purchasing natural, less processed products, without chemical additives

and preservatives. Therefore, food producers and technologists face the challenge of supplying products without artificial additives, preservatives or dyes, but at the same time of high quality and with a long shelf life. Although there is no formal definition of what constitutes a 'clean label', leading to a variety of approaches by manufacturers and different interpretations by consumers, the common denominator is the lack of or low processing, a short list of ingredients, a lack of synthetic additives [1, 2].

This study provides a review of research on the replacement of artificial preservatives in meat products with traditional chemical compounds of natural origin. On the basis of data from the Central Statistical Office (Fig. 1), meat consumption in Poland has increased slightly since 2005. However, since 2010 it has remained relatively constant. We still consume pork meat in the largest quantities, the consumption of poultry is increasing, while the consumption of beef meat is decreasing. While demand and consumption remain stable, rising living standards and greater choice mean that consumer preferences are moving towards meat products that are more natural, healthy and safe, while remaining cheap and with good sensory properties. Manufacturers are responding to the increasing demand for quality by creating new recipes based on natural ingredients [1, 3].

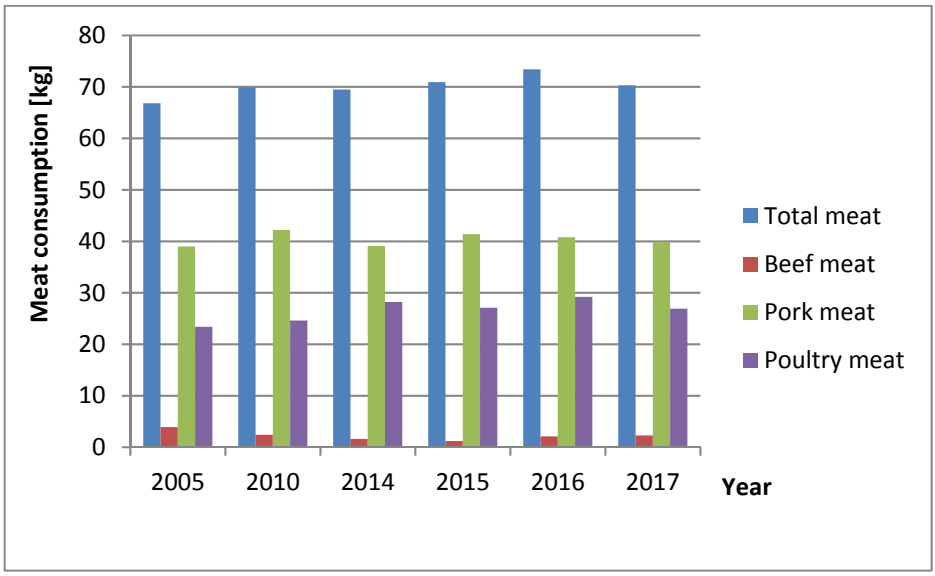

Figure 1. Meat consumption (kg) per person in Poland in years 2005-2017; Source: Central Statistical Office (GUS) [3]

Food preservation

The first methods of food preservation were fermentation (spontaneous) and cooling. In ancient times, around 589 BC, a fermented sausage consisting of goat and lamb meat was produced in China. From 356 BC, the Vikings refrigerated food

in ice and snow pits [1]. Food was also stored in caves. In 1811, Nicolas Appert developed the appertisation process, still used today, whereby food is preserved in closed containers [1]. The production of preserved food on an industrial scale began with the use of pasteurization at the end of the 18th century.

In the second half of the 19th century, the first refrigerators appeared, while in the 20th century new methods of preservation were developed such as ionizing radiation, high-pressure techniques, ultrasound, pulsating electric fields, magnetic fields and lyophilization. The use of active packaging made of materials with specific properties, or with special inserts, also extended the shelf-life of products [1]. The most commonly used method for prolonging the freshness and quality of the meat is freezing. As a result of which slowed are microbiological, chemical and biochemical changes [12].

According to Moszyński [4], the first methods used to preserve food in Polish lands were drying and fermenting. These were also used by Slavs living in north-eastern Europe and northern Asia. Wild goose meat, fish, potatoes, beets, cabbage and other vegetables were acidified. Fish and meat were traditionally placed on sun-warmed stones or in ovens, and then stored in bags suspended in a ventilated place. Fruit, mushrooms, nuts, herbs and rhizomes of medicinal plants were also subjected to this process. Another method used to preserve food is smoking. Smoked fish and meats last longer due to the action of organic acids, phenols, creosote and formaldehyde present in smoke, which inhibit the growth of microorganisms that cause rotting and prevent the fat from oxidizing. The product has a characteristic smell, taste and appearance [5]. From ages salt was used as a natural preservative for meats. It works by reducing the growth of microorganisms, reduced water activity, the formation of deliciousness and increasing of water uptake. The effect of salt depends on the concentrations applied to the meat [12].
Methods of food preservation may be used to:

- protect against pests,
- inhibit the development of pathogenic microorganisms,
- stop biochemical, chemical and physical changes,
- protect against biological, chemical and odoriferous contamination.

They should function reliably and maintain the natural characteristics of the products [6, 7].

Permitted preservatives

Food additives are divided into 8 main groups, including preservatives (Fig. 2) [8].

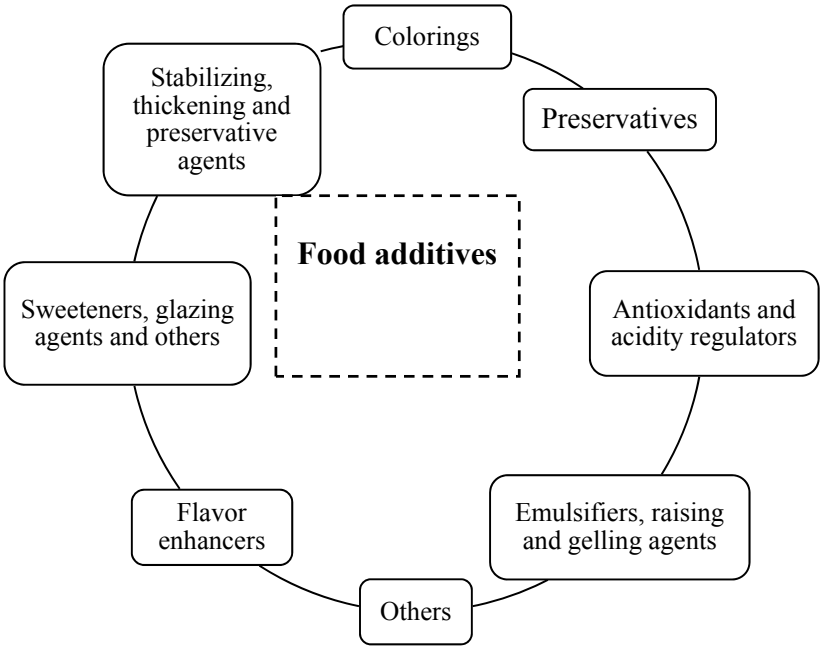

Figure 2. Division of food additives – own elaboration based on [8]

Regulation (EC) No. 1333/2008 of the European Parliament and of the Council of 16 December 2008 describes preservatives as food additives that extend the shelf life of foodstuffs by protecting them against deterioration caused by the presence of microorganisms or against the growth of pathogenic microorganisms [9]. They should be added in small amounts (less than 0.2%), in accordance with the quantum satis rule, i.e. at the lowest possible dose to achieve the intended effect [8, 10]. Preservatives and exemplary antioxidants that have been used in the meat industry are described in Table 1.

Important properties of preservatives include antimicrobial action in small quantities, resistance to oxidation, high temperatures and acidic environments, solubility in water and low production costs. They should not deteriorate the organoleptic features of the foodstuff or have toxic effects on the human body in the quantities used. The products of their decomposition should be metabolized quickly and not accumulate in fatty tissue or bones. They should survive the technological processes to which food products are subjected [8, 11].

Table 1. Selected additives applicable to meat products [8, 12]

Type of additive	Effect	Undesirable effects	Application
Potassium nitrate (III) (E249)	Inhibits bacteria, in particular *Clostridium botulinum*, which produces botulinum toxins. Preservative activity increases lower pH.	Dizziness and headaches, asthma, toxic in large quantities, carcinogenic compound nitrosamines may form in reactions with amines derived from the decomposition of proteins in the human body.	Cured, picked, smoked meat products; fish preparations.
Sodium nitrate (III) (E250)		Potentially carcinogenic, may cause nausea, vomiting, dizziness and headaches.	Cured, canned, sterilized and pasteurized meat products.
Ascorbic acid (E300)	Antioxidant and preservative properties, regulates acidity, protects food against rancidity and oxidative browning.	Not toxic, but can cause nausea, diarrhea, vomiting and stomach ailments at doses of more than 2 g per day.	Cured meat, sausages.
Citric acids (E330)	Antioxidant, stabilizing, acidifying and taste properties. Strengthens the color of meat products.	Harmless in small doses.	Meat products, preserved vegetables and meat products
Lactic acid (E270)	Bacteriostatic properties against pathogenic microflora and inhibits the development of bacteria that cause decay. An acidity regulator.	Harmless in small doses.	Raw sausages, fast-maturing sausages

Natural preservative

The food industry is in a constant struggle with pathogens such as *Salmonella* spp., *Shigella* spp., *Enterococcus faecalis*, *Escherichia coli*, *Listeria monocytogenes, Staphylococcus aureus*, *Campylobacter jejuni*, *Yersinia enterocolitica*, *Vibrio parahemolyticus*, *Escherichia coli* 0157: H7 and *Clostridium botulinum*. New solutions for food preservation are therefore continually sought in order to ensure food safety and quality [13].

The increasing demand for healthy food is incentivizing manufacturers to develop new technologies and find alternatives to chemical preservatives in the form of natural ingredients. Plants have been used since ancient times to improve sensory properties and extend shelf life, as well as in folk medicine to relieve pathogenic symptoms in the human body. Table 2 lists common natural plant extracts and essential oils used in meat products, their effects and major studies in the literature.

Table 2. Natural plant extracts and essential oils used in meat products

Factor	Application	Effect	Literature
Essential oil			
Rosemary	Mortadella	Antioxidant	Viuda-Martos et al. [14]
	Pork liver pate	Antioxidant	Estevez et al. [21]
	Pork frankfuters	Antioxidant	Estevez and Cava [25]
	Pork sausage	Antioxidant	Sebranek et al. [24]
Oregano	Bologna sausage	Antioxidant	Viuda-Martos et al. [15]
	Ground porcine/ bovine meat	Antioxidant	Fasseas et al.[22]
	Fresh chicken breast	Antioxidant	Chouliara et al. [23]
	Chicken liver meat	Antioxidant	Hasapidou and Savvaidis [20]
	Bologna slices	Antimicrobial	Zivanovic, et al. [56]
Clove	Minced beef	Antioxidant	Zengin and Baysal [16]
	Fresh chicken sausage	Antioxidant	Kumar et al. [18]
	Mutton nuggets	Antioxidant	Sharma et al. [19]
Thyme	Chicken breast meat	Antioxidant	Fratianni et al. [17]
	Mortadella	Antioxidant	Viuda-Martos et al. [14]
	Fresh chicken sausage	Antioxidant	Sharma et al. [19]
	Minced beef	Antioxidant	Zengin and Baysal [16]
Plant extract			
Rosemary	Pork patties	Antioxidant	Nissen et al. [28]
	Raw frozen and precooked frozen sausage	Antioxidant	Sebranek et al. [24]
Nettle	Ground beef	Antioxidant	Alp and Aksu [26]
Green tea	Cooked pork	Antioxidant	Wojciak et al. [29]
	Raw and cooked goat meat	Antioxidant	Rababah et al. [30]
	Chicken hot dogs	Antimicrobial	Perumalla et al. [57]
	Cooked pork meatballs	Antimicrobial	Price, Díaz, Bañón, and Garrido [58]
Curry leaf	Raw ground pork meat	Antioxidant	Biswas et al. [27]
Mint leaf	Raw ground pork meat	Antioxidant	Biswas et al. [27]
Grape seed	Cooked beef, pork patties	Antioxidant	Rojas and Brewer [31]
	Turkey frankfurters	Antimicrobial	Sivarooban, et al. [59]

Essential oils

Essential oils are volatile, liquid substances made from different parts of plants: roots, leaves, flowers, peel, fruits. They are used in the food industry to give aromas and as preservatives, as well as in medicine. Essential oils have wide range of applications due to their antioxidant**,** antifungal and antimicrobial properties. They show broad antimicrobial activity against many bacteria, including *Listeria monocytogenes*, *Salmonella*, *Bacillus cereus*, *Escherichia coli* O157: H7, *Staphylococcus aureus* and *Yersina enterocolitica* [32]. Examples of essential oils derived from spice plants which are used in meat products are given in Table 3.

Table 3. Natural essential oils used in meat products[8]

Essential oil	Part of the plant	Use
Basil	Flowering herb	Canned meat
Stone	Herb, leaves	Meat, canned meat
Caraway	Fruit	Meat preparations
Marjoram	Flowering herbs	Meat products
Pepper	Fruit	Meat preparations
Rosemary	Flowering herbs, leaves	Meat preparations
Thyme	Flowering herbs	Canned meat

In recent years, there have been increasing numbers of studies on essential oils (Fig. 2) and their component compounds. These are primarily secondary plant metabolites, such as sesquiterpenes, terpenes, aliphatic and aromatic alcohols, ketones, aldehydes, acids and others[8].

Several studies have described the traditional use of essential oils in food. Macura et al. (2011) studied the influence of various essential oils including coriander and lemon balm on the quality of minced veal meat. The oils were used individually at concentrations of 0.02% and as a mixture containing 0.01% of each. They studied the effect of the extracts on the growth and amount of bacteria belonging to the family *Enterobacteriaceae,* lactic fermentation bacteria, moulds and yeasts. The addition of oils inhibited the growth of the *Enterobacteriaceae* and molds. However, it did not inhibit the development of other microorganisms [33].

Due to the fact that essential oils can have a significant effect on the organoleptic properties of products, which is not always positively evaluated by consumers, new ways to add them to food are being sought. One possible method is microencapsulation. Jemaa (2018) used Nano encapsulated essential oil from thyme (*Thymus capitatus*) as a natural preservative for food. In order to intensify the action of thyme essential oil, a nanoemulsion was prepared. Increased antibacterial activity was observed against *Staphylococcus aureus*, *Escherichia coli*, *Enterococcus hirae*, *Bacillus licheniformis* and *Pseudomonas aeruginosa*. The oil in the nanocapsule also had higher antioxidant activity in comparison to that without encapsulation [34].

Plant extracts

Extracts from natural plant raw materials may be obtained by the use of solvents – water, ethanol or hexane [8]. Plants contain polyphenolic compounds with pro-healthy effects on the human body. They are found in various parts of plants, including the roots, leaves, fruits and flowers. They have many beneficial properties. For example, they are natural antioxidants, strongly scavenge free radicals and show anti-inflammatory, anticancer, antimutagenic and anti-allergic effects [37]. Extracts based on spices and herbs could provide an alternative to chemical preservatives in meat products. Shan et al. [36] conducted research on the preservative effect of extracts from cinnamon, cloves, oregano, pomegranate peel and grape seeds on raw pork meat. The results showed the extracts had an inhibitory effect on bacterial growth, in particular against *Salmonella enterica*, *Listeria monocytogenes* and *Staphylococcus aureus*. Changes in the color of the meat and oxidative changes in the fat were also investigated. The addition of extracts increased the stability of fats [36].

The effect of extracts from dried nettles, lovage, oregano and horseradish on the quality of pork meat has also been investigated. Grâmatiòa et al. (2017) showed that the addition of nettle extract prolonged the quality of meat stored in vacuum packaging by up to 22 days. The addition of lovage, oregano and horseradish extracts extended shelf life to 32 days, while in the control sample without any added extract qualitative changes were observed after 18 days [37].

Other studies have examined the effect of adding sage to meat. Sage is a spice plant with antioxidant and antibacterial activities. Hać-Szymańczuk and Cegiełka (2015) assessed the effect of the addition of water extract from dried sage (2.0%), of 40% alcoholic extract from dried from sage (2.0%), and of 70% alcoholic dried extract from sage (2.0%) on the lipid oxidation process and microbiological quality of pork products. It was found that the addition of sage slowed down the oxidative processes of lipids occurring during meat storage. Water and alcohol extracts inhibited the development of microorganisms most effectively, including those belonging to the *Enterobacteriaceae* family, psychrotrophic microorganisms and enterococci. On the other hand, in the dried extract did not inhibit the growth of microorganisms [38].

Sang-Keun et al. (2018) analyzed the effect of various natural fixatives as alternatives to nitrates in sausages: pomegranate powder extract 17.00%; lemon 4.50%; beetroot 1.00%; rosemary 22.00%; glucose 55.00%; salt 1.50%; fruit and vegetable powder extract 0.5% containing radish powder 42.90%, beet 40.60%, blackcurrant 5.49%, apple 5.50% citric acid 6.00% and maltodextrin 3.00%; gardenia red 0.04%; powdered berry and pepper 0.07%. The best substitute for nitrates was found to be extract from celery powder. Similar results were obtained in terms of sensory evaluation, total number of microorganisms and TBA to the those for the control sample containing 0.01% sodium nitrate. Celery powder not only gave the desired color and did not deteriorate taste, but it also positively influenced the physicochemical properties of the sausage meat during storage [39].

Antimicrobial peptides

Antimicrobial peptides are natural proteins of plant and animal origin. They are oligopeptides consisting of between 5 and 100 amino acids. Peptides are formed as a result of protein hydrolysis, fermentation or enzymatic hydrolysis in vitro. They were discovered in 1939 by Dubos, who extracted an antimicrobial agent from the *Bacillus brevis* strain. The extract was administered to mice and it was demonstrated that peptides have protective properties against pneumococcoccal infections [40].

The first antimicrobial peptides isolated from food proteins were caseins derived from cow's milk casein, which was hydrolyzed with chymosin [41]. In their natural state, caseins occur in cationic form, contain hydrophobic amino acids and have a wide range of activity against viruses, bacteria and fungi [41]. The mechanism of action of these bioactive peptides is still not fully understood. However, they cause a number of interactions, such as destabilizing lipid structure, changing cell membrane permeability and stopping DNA replication [41].

Over the last twenty years, peptides have been the subject of many studies. They have been characterized as having a number of interesting properties: antioxidant, anti-inflammatory, antihypertensive and antimicrobial [43]. Those with antimicrobial properties are of particular interest to the food industry. So far, only nisin is permitted for use in food preservation [42]. However, in the near future antimicrobial peptides are likely to play a more significant role [13]. Due to features such as low cytotoxicity, a wide spectrum of action, no production of mutants in vitro and resistance to proteolytic enzymes, they may offer a good alternative to chemical preservatives, reducing the amounts of harmful microorganisms and prolonging shelf life [41, 44, 45].

Table 4. Selected antibacterial peptides

Peptide name	Source	Activity aganist microorganisms	Literature
Enterocin NKR-5-3B	*Enterococcus faecium* NKR-5-3	Gram + *Bacillus coagulans, Enterococcus faecium, Bacillus circulans*	Himeno K. et al. [46]
Plantaricin JLA-9	Chinese fermented vegetables (Suan cai, or Suan Tsai), *Lactobacillus plantarum* JLA-9	Gram + , Gram - *Bacillus cereus Salmonella enteritidis, Escherichia coli, Penicillium notatum*	Zhao S. et al. [47]
Plantaricin Y	*Lactobacillus plantarum* 510	Gram + *Listeria monocytogenes*	Chen YS. et al. [48]
Lactolisterin BU	*Lactococcus lactis* subsp. lactis bv. diacetylactis BGBU1-4	Gram + *Listeria monocytogenes*, *Staphylococcus aureus*, *Bacillus* spp.	Lozo J. et al. [49]

Table 4. continued

Enterocin LD3	*Enterococcus hirae* LD3	Gram +, Gram - *Staphylococcus aureus, Pseudomonas fluorescens, Pseudomonas aeruginosa, Salmonella typhi, Shigella flexneri, Listeria monocytogenes, Escherichia coli*	Gupta A. et al. [50]
Bakteriocin TSU4	*Lactobacillus animalis* TSU4	Gram + , Gram - *Pseudomonas aeruginosa, Aeromonas hydrophila*	Sahoo TK et al.[51]
Hyicin 3682	*Staphylococcus hyicus* 3682	Gram + *Micrococcus luteus*	Fagundes P.C. et al. [52]
F3	Sour yoghurt	Gram +, Gram - *Escherichia coli, Staphylococcus aureus*	Miao J. et al. [53]

Another alternative to chemical preservatives is lysozyme. This is a protein found in plants, animals, viruses and bacteria. The richest source of lysozyme is egg white. It has antibacterial, antifungal and antiviral properties. It is active across a wide range of pH levels, from 6.0 to 9.0, and if it is in powder form it can be stored for several years at a temperature of -20°C. Due to these properties and its safety, in 1992 the WHO/FAO commission issued a permit allowing use of lysozyme for food preservation. It is used on an industrial scale in many countries, including Belgium, Italy, Austria, France, Germany and Japan, where a patent has been registered for preserving fruit, vegetables, fish and meat by covering their surfaces with lysozyme [8, 54].

Summary

In recent years, there has been increasing interest in possible alternatives to chemical preservatives used in meat products. Much research has been carried out with the aim of replacing synthetic natural preservatives in meat and meat products while maintaining the qualities desired by consumers. As we have seen in this review, one solution is the use of essential oils of natural origin, which have antioxidant, antibacterial and antifungal properties. Plant extracts with antioxidant and anticancer properties offer another alternative to chemical preservatives used in food, as do antimicrobial and antibacterial peptides. Increased consumer awareness of the possible dangers of artificial additives is leading to greater demand for food with little or no processing, which is local and safe.

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