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Review Article

Lycopene as a Natural Food Additive for Improving Meat Products Quality

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Abstract

Meat products contain protein, which is important for growth needed by human body, in addition to contain some minerals and vitamins as iodine, iron, zinc, and B12. This high nutritional value of meat products makes them vulnerable to spoilage and difficult to be preserved. Natural preservatives have emerged as alternatives to chemical preservatives. Natural additives have shown potential to provide effective antimicrobial and antioxidant activity while reducing negative health impacts. Incorporating lycopene into meat products has gained much interest among food scientists and in the meat industry. Some past articles concerning the lycopene addition effect on the quality of meat products have been published. Based on the above, the purpose of this review is to provide an overview of the applications of lycopene as a natural colorant and antibacterial in meat products, and to provide a comprehensive summary of the effectiveness and progress of lycopene in the preservation of meat products over the last decade. The information in this review provides ideas for future applications of lycopene in meat preservation as a natural antioxidant, which has great potential to replace traditional artificial preservatives.

KEYWORDS
Meat, Lycopene, Preservatives, Natural.

Introduction

Meat and meat products are important sources of high-quality protein in the human diet. It is a rich source of essential vitamins and minerals (Iron, Zinc) that are efficiently absorbed by the human intestine (Grasso *et al*., 2022). However, the high nutritional value of meat products also makes them difficult to be preserved. Spoilage is the most common problem which easily occurs during meat processing, transportation, storage, and sale. Meat products gradually reach the unacceptable limit of flavor, color, and texture under the actions of microorganisms or metabolic processes (Bekhit *et al*., 2021).

The urgent need to feed the growing world population along with increasing consumer expectations and awareness has led to the development of food production systems and products applied in the food industry. Although great progress has been made in food additives, the controversy that still rages around some of them encouraged the search for safer and healthier future generations. These additives can provide many health benefits, in addition to coloring or preserving purposes (Cláudia Novais *et al*., 2022).

Recently, there has been increasing concern about the safety of food additives used to extend the food products shelf-life (Li *et al*., 2023). However, despite their obvious benefits, it should be noted that a large percentage of the approved food additives are synthetic in nature and, when used improperly, have a host of side effects as toxicity and other harmful interactions that have carcinogenic and dangerous capabilities to the health of the consumer (Martins *et al*., 2016).

The industrial transformation of vegetables and fruits generates large quantities of byproducts rich in bioactive compounds that may well be suitable for other purposes (Viuda-Martos *et al*., 2009). Tomato by-products contain a great variety of biologically active substances, principally lycopene, which have been proven by studies to possess natural red colorant, antioxidant, hypolipidemic and anticarcinogenic activities (Viuda-Martos *et al*., 2013). There is a fact that humans are unable to synthesize lycopene, and thus a supply of it in food is necessary to take benefits of its health-beneficial properties. Recently, more and more clinical trials are seeing several important health benefits in lycopene, including its protective effect on cardiovascular disease (Puah *et al*., 2021).

Tomato extract also inhibits the growth of some important pathogens when added to meat and this antibacterial activity is due to presence of active components of tomato (lycopene) in extract on some bacteria (Al-Oqaili *et al*., 2014).

Growing concern to environmental protection is leading food industries to adopt a model of "circular economy" applying safe and sustainable technologies to recover and recycle by-products. Thus, by-products become raw material for other industries (Madia *et al*., 2021). Therefor this review was carried out to through a light on the effect of using the environmentally friendly lycopene as a natural food additive to improve meat products quality.

Microbial Contamination of Meat

Contamination of meat products may additionally be befell at some point of preliminary processing, packaging and stor-

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age till the product is sufficiently cooked and consumed. Heavy bacterial masses enter into the processing operations with the dwelling cattle and these microorganisms can be disseminated at some point of the plant throughout processing. Meat products are rich in various nutritive substances; they can easily be attacked by different microorganisms, which are widely distributed in the environment. Processed meats are more susceptible to microbial contamination during different stages of processing. Hence, it is of utmost importance to screen the microbial quality of meat products to deliver better quality and safety (Abuelnaga *et al*., 2021). Microorganisms count is one of the most important indicators to evaluate the freshness of meat. Meat is favored by millions of people worldwide as a major supply of animal protein but it is considered a favorable medium for the growth of different pathogens, so it acts as a hygienic risk problem to the consumer (Elsayed *et al*., 2018).

Meat is a perishable product. At slaughter, the inherent protective barriers (e.g., skin) and natural defense mechanisms (e.g., antimicrobial peptides) of live animals break down. This allows microorganisms to a rapid grow and decompose muscle tissues. Changes caused by microorganisms lead to the formation of discoloration, off-odors, and slime, making meat become unacceptable to consumers and limiting the product shelf-life (Iulietto *et al*., 2015; Comi, 2017). Moreover, the contaminating microorganisms are derived from the hide of the animals and involve organisms that originate from stomachs and intestines, which are excreted in their feces (Norrung *et al*., 2009). Microorganisms from animals themselves, the workers, and the processing environment are transferred to meat during processing (Zagorec and Champomier-Verges, 2017). Wooden boards, knives and weighing scales from retail shops are sources of bacterial contamination, particularly *Staphylococcus aureus* and *Shigella* species (Ali *et al*., 2010).

Meat and meat products are constituted as major causes of most known food poisoning outbreaks. Therefore, it is crucial to use microbiological criteria to detect the quality of those products (Abuzaid *et al*., 2020). Foodborne diseases are diseases resulting from ingestion of bacteria, toxins, and cells produced by microorganisms present in food (Okonko *et al*., 2010). Food-borne pathogens, including *Staphylococcus aureus*, *Listeria monocytogenes*, pathogenic *Escherichia coli*, *Clostridium perfringens*, *Campylobacter* spp., and *Vibrio* spp., cause a large number of illnesses, with fundamental damage to human health and economy (Lee and Yoon, 2021).

Bacterial counts of meat are used as an acceptable indicator of its hygienic quality. The poor infrastructural facilities in slaughter houses, unhygienic animals, and poor handling of carcasses attribute to the high bacterial load in meat, by assessing the bacterial counts, the threat posed to human health can be ascertained (Birhanu *et al*., 2017). Of the 340 meat samples, 84% were found to be contaminated with bacterial species such as *Staphylococcus aureus*, *Klebsiella*, *Bacillus subtilis* and *Enterobacter*. A total of 550 (66%) bacterial isolates were potential pathogens. Of these, 342 and 208 strains were isolated from meat and environmental samples, respectively. Foodborne pathogens isolated from meat samples included *Salmonella*, *Escherichia coli* O157:H7, Listeria, enteritidis and *Trichophyton* spp., while from environmental samples *Staphylococcus aureus* and Staphylococcus spp. were detected. Four strains of the genus Brucella were also isolated from meat samples. Total aerobic values ranged from 10^8 to 10^{10} CFU/g or cm^2. Resistance to various antibiotics has been observed. Resistance rates to ampicillin, amoxicillin, novobiocin, and cefaclor generally ranged from 62 to 75% (Ali *et al*., 2010).

It is generally recognized that the most significant foodborne hazards from fresh meat are bacteria that can cause disease in humans (pathogenic bacteria), such as *Salmonella*e species, *Staphylococcus aureus*, *Escherichia coli* O157: H7, *Listeria monocytogenes* and *Campylobacter* species. Some of these, particularly *E. coli* O157: H7, require only a few bacteria to cause food poisoning in humans (Birhanu *et al*., 2017). Microbiological assessment of meat products during marketing should be introduced to ensure meat safety and quality. However, there will be a need to devise efficient safe methods to prolong the shelf-life and safety of meat products under storage conditions.

Meat Preservatives

Food preservation plays an important role in extending food products shelf-life and is closely related to their quality and sensory properties (Huang *et al*., 2023). Meat available at retail markets should be stable quality and free from pathogenic bacteria and fungi which cause serious diseases. Fresh meat is often treated by cooling or freezing to increase its shelf-life. Refrigeration and freezing processes are the common methods used to protect foods by preventing the microbial growth that cause food-borne illnesses (Hammad *et al*., 2017, Albrecht *et al*., 2019).

Shelf-life affects everyone in the food supply chain. For consumers, inadequate shelf-life often leads to dissatisfaction, which will then affect the acceptance and the sales of the product. As a result, supermarkets generally do not accept products with less than 75% of shelf-life remaining (Robertson, 2013). Improving meat quality and safety is of great importance for human well-being. Since prehistoric times, human have improved diet and hunting, domesticating animals and vegetables, preserved food by physical methods and finally by adding molecules to food to enhance flavors or to preserve it (Branen *et al*., 2001).

Recently, many food products in the market are preserved using multiple methods. Refrigeration and packaging systems are widely used for fresh meat, and other preservation technologies have also been developed or proposed to control microbial growth and extend product shelf-life. Besides physical (e.g., high pressure processing, ultrasound and ionizing irradiation) and chemical (e.g., organic acids, peracetic acid, and nanoparticles) approaches, there is an increasing demand for natural preservation methods and minimally processed food (Rosario *et al*., 2020). However, each year a huge quantity of precious animal protein is wasted due to a lack of proper meat preservation infrastructure. Among various factors causing meat spoilage, lipid and protein oxidation, microbial growth, and enzymatic action are the main perpetrators for quality degradation and huge loss of meat and fish across the globe (Bekhit *et al*., 2021).

The food industry has advanced worldwide, resulting in an increased risk of food contamination by pathogenic microorganisms, harmful food additives, chemical residues, and toxins. The multiplication of pathogenic microorganisms and spoilage should be controlled to ensure food safety. Accordingly, food preservation techniques for protecting food from pathogenic bacteria and extending shelf-life include chemical methods, such as the use of preservatives; physical methods, such as heat treatment, freezing, drying and packaging; and biological methods using microorganisms that have an antagonistic effect on the pathogenic bacteria and produce bacteriocins (Matthews *et al*., 2017). Furthermore, the addition of food preservatives that inhibit the growth of microorganisms is a widely used food protection technique (Yu *et al*., 2021).

However, chemical and synthetic preservatives, such as nitrates, sodium benzoate, potassium sorbate, etc., have been widely used in food preservation (Piper and Piper, 2017). They are very cheap and widely used in the food industry, but according to recent studies, long-term consumption of products containing artificial preservatives and additives may cause many physical hazards involving neurotoxicity, accelerated aging, teratogenic, and a range of other effects (Sambu *et al*., 2022). Nitrite was the first additive to serve the coloring purpose because it gives the meat product a red curing color (Feiner and Feiner, 2016), however, nitrite is known as a toxic additive, and a prolonged intake of nitrite in the diet was reported to be linked to different types of diseases (Agency for Toxic Substance and Disease Registry 2005, New Hampshire Department of Environmental Service, 2006). Natural preservatives, which are considered a better alternative to artificial additives, have shown the potential to provide effective antimicrobial activity while minimizing negative health effects. Meat and meat products containing artificial additives are considered a major human health concern (Yong *et al*., 2021).

Preservatives and antioxidants are used together to preserve foods. Preservatives are used to prevent spoilage and antioxidants are used to delay chemical oxidization processes that produce unpleasant tastes and odors (Franco *et al*., 2019). The recent scientific development of antioxidants and their impact on human health has led to an increase in the importance of natural antioxidants. Many societies around the world have benefited from natural antioxidants in treating various diseases and improving human health. An unhealthy diet is a major cause of many medical conditions, including cardiovascular disease (Costa-Rodrigues *et al*., 2018; Mohammed *et al*., 2018).

Plant and botanical extracts are used for medicinal purposes such as disease prevention because the protective system in plants and its bioactive compounds prevents various stress damages of active oxygen (Costa-Rodrigues *et al*., 2018; Mohammed *et al*., 2018). In addition, as the concept of food safety and health becomes more widespread, consumers pay more attention to the naturalness and safety of products when purchasing them. Therefore, the use of natural preservatives and antioxidants from plants and other natural sources to extend the shelf-life of foods has become the subject of great research interest in recent years and can be an effective alternative (Li *et al*., 2023).

Lycopene as a Natural Meat Preservative

Meat products are a well-liked and well-accepted product by consumers around the world. Consumers are recently looking for nutritious and safe meat products. This demand has driven meat processors to develop products that can meet consumer requirements using new techniques that include reducing chemical preservatives and supplementing the products with natural non-meat additives (Viuda-Martos *et al*., 2009, Verbeke *et al*., 2010).

According to World Health Organization (WHO) medicinal plants would be the best source to obtain a variety of drugs. About 80% of people from developed countries use traditional medicine, which has compounds derived from medicinal plants (WHO, 2002). Tomato is the most widely produced and consumed fruit and vegetable worldwide besides potato, with more than 182 million tons produced worldwide on over 5 million hectares of cultivated area (Caruso *et al*., 2022; Makhadmeh *et al*., 2022). The tomato processing industry generates large amounts of waste, especially tomato peels and seeds which create environmental problems. These residues are attractive sources of bioactive ingredients and pigments. Lycopene is one of the carotenoids, a fat-soluble pigment that has antioxidant properties (Soumia *et al*., 2019).

Tomato by-products (TBP) are a source of valuable compounds: vitamins dietary fibers, minerals, proteins, polyphenols and carotenoids (Fărca *et al*., 2019). Recently, there has been growing concern about the safety of additives used to extend the shelf-life of food products. As a result, lycopene has attracted interest, as it has been demonstrated to be a potential alternative to traditional synthetic antioxidants, with significant health benefits when applied to food preservation (Li *et al*., 2023). Tomato skin is very rich in lycopene, and from its seeds, high nutritional oil can be extracted. The alternative use of the tomato industrial waste not only could decrease disposal costs but also allow one to extract bioactive compounds and an oil with a high nutritional value (Madia *et al*., 2021).

Lycopene is an oil-soluble carotenoid with an aliphatic hydrocarbon chain, its molecular formula is C40H56 (Srivastava, 2019). Lycopene has been found to be an excellent choice in the search for alternatives to synthetic antioxidants. It is a type of natural phytochemical compound mainly present in tomatoes and is commonly extracted or purified through organic solvents (Oberoi and Sogi, 2017). Lycopene is a carotenoid abundantly found in red vegetables. This natural pigment displays an important role in human biological systems due to its excellent antioxidant and health-supporting functions, which show a protective effect against cardiovascular diseases, hypertension, cancers, and diabetes (Li *et al*., 2018, Liu *et al*., 2020).

Lipid oxidation is the main non-microbial cause of quality deterioration of meat and meat products. Oxidative reactions reduce the nutritional value of meats, produce many toxic compounds that can promote multiple diseases and reduce its sensory quality. With this in mind, the main strategy used by the meat industry to inhibit lipid oxidation is adding antioxidants to meat and meat products (Domínguez *et al*., 2019). To this regard, colour is the most important parameter that influences consumer acceptance of any product especially meat products (Deda *et al*., 2007).

There is a well-documented influence of lycopene on the meat product colour, the sensory quality of the products depends strongly on the amount and the source of lycopene, the nature of the food matrix and its composition (Modzelewska-Kapituła, 2012). Meanwhile, researchers usually report that lycopene positively affects color scores in the sensory evaluation of foods in studies that have been conducted. This may be attributed to the inherent color properties of lycopene, which is dark red at high concentrations (>100 ppm) (Li *et al*., 2023). Tomato powder added in amounts of 2.0% and 2.5% to a comminuted meat product increased its sensory acceptability and oxidative stability, changed the colour towards more red and decreased pH, although it had no influence on cooking losses (Modzelewska-Kapituła and Więk, 2019).

From a microbiological standpoint, tomato extract has inhibiting the growth of some important pathogens and this antibacterial activity is due to presence of active components of tomato (lycopene) in extract on some bacteria (Al-Oqaili *et al*., 2014). Lycopene showed antibacterial and antifungal activity against all tested microorganisms including gram positive (Bacillus cereu EMCC 1080 and *Staphylococcus aureus* ATCC 13565) and gram negative (*Escherichia coli* O157-H7 ATCC 51659, *Salmonella* typhi ATCC 15566 and Pseudomonas aeruginosa NRRL B-272). Gram positive bacteria found to be more susceptible than gram negative ones. *Bacillus cereus* recorded the highest inhibition zones among all tested bacteria with inhibition zone 15.3 mm for lycopene (Habiba *et al*., 2021). Lycopene can play an antimicrobial role due to its antioxidant activity. There was alteration in the antibacterial activity of lycopene extract from tomato by simple solvent. More activity was shown in the highest concentration (100 mg) in each type of bacteria that used. Lycopene have inhibitory potential in contrast to some of microbes, and Pseudomonas aeruginosa is the most affected (Rawaa *et al*., 2020). Furthermore, the microorganisms such as *S. aureus*, *Bacillus, Proteus*, also, antifungal *Aspergillus niger* and *C. albicans* affected by Tomatoes extract (Sung *et al*., 2007). Tomato by-products delayed meat deterioration to a varying extent, so that the shelf life of treated beef patties ranged between 8 and 12 days (Sanchez-Escalante *et al*., 2003).

The lycopene intake has multiple health benefits that have been well documented. For example, dietary lycopene exhibits important bioactivity in the prevention and treatment of cardiovascular diseases (Przybylska, 2019). Several epidemiological evidences have related higher lycopene consumption with lower risk of prostate cancer (Rowles *et al*., 2018). Due to its antioxidant properties and lipophilic nature, the lycopene has also been investigated for its potential role in the prevention of lesions caused by oxidative stress at the brain level (Wu *et al*., 2015).

In addition, researchers have found that through antioxidant anti-inflammatory, and antiproliferative activities, lycopene may exert preventive and therapeutic effects on different central nervous system illnesses, including Parkinson's disease, Alzheimer's disease, cerebral ischemia, epilepsy, and depression. In rodents with various clinical diseases, such as diabetes, high-fat diet, colchicine exposure and aging, lycopene also enhances cognition and memory. In addition, lycopene protects against neurotoxicity induced by organic and inorganic pollutants, such as methylmercury, tertbutyl hydroperoxide, and cadmium (Leh and Lee, 2022, Ataseven *et al*., 2023). Moreover, an antioxidants rich diet could be promising for the prevention and treatment of many diseases like COVID-19, but robust clinical research data is needed to support this claim (Lammi and Arnoldi, 2021). The pandemic that has heightened public health concerns for consumers and created opportunities for innovative functional foods that contain targeted bioactive compounds, such as lycopene (Galanakis, 2020; 2021).

Lycopene is insoluble in water, barely soluble in ethanol, while it has high solubility in lipids and non-polar organic solvents (Lu *et al*., 2019). Thus, both, lycopene and other carotenoids are usually extracted employing organic solvents and are also industrially produced by chemical synthesis. Since these processes involve the use of highly toxic chemical solvents, interest has increased in the use supercritical fluid extraction (SFE) as a solvent alternative to the industrial production of lycopene (Viuda-Martos *et al*., 2014). Some new extraction methods have been recently applied, such as using supercritical carbon dioxide (SC-CO_2) extraction, combining SC-CO_2 extraction with microwave irradiation pre-treatment, or even directly producing lycopene from CO_2 in photoautotrophic bacteria (Honda *et al*., 2018, Li *et al*., 2022).

Conclusion

Incorporating lycopene into meat products as a natural additive and antioxidant provide the opportunity to introduce "clean label" products with nutritional and health benefits to the consumer.

Conflict of interest

The authors declare that they have no conflict of interest.

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