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IMPROVING EFFECTIVENESS OF POLYPHOSPHATES ON FOOD QUALITY AND SAFETY IN READY TO EAT MEAT PRODUCTS BY ENCAPSULATION TECHNOLOGY

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Abstract

Protecting consumer health through improving food safety and quality has been an increased focus for both food processors and researchers. Meat and meat product manufacture is vital step for occurrence of microbial contamination in a ready-to-eat (RTE) meat products. Contamination of RTE meat products with pathogenic microorganisms such as Listeria monocytogenes, Escherichia coli, Salmonella spp. and Staphylococcus aureus, or spoilage microorganisms like Pseudomonas spp. can creates life-threatening foodborne illnesses for consumers or causes consumers to avoid meat purchase. In addition, spoilage microorganism contamination in RTE meat products impairs sensory quality, intensifies perishability of these products, and reduces their shelf life. Therefore, foodborne outbreaks cause recalls and negative publicity which can result in a decrease in meat and meat purchases by consumers. Therefore, meat processors and researchers constantly searching for strategies to control potential bio-hazards in RTE meat products. Various food additives are utilized in the product formulations to control the growth of undesirable microorganisms in muscle foods. Polyphosphates (PP) are commonly used in various meat product processing for their beneficial effects such as improved water binding capacity and cooking yield, accelerated curing process, reduced lipid oxidation and improved textural attributes. PP also have the capability of inhibiting the growth of several Gram-negative, Gram-positive bacteria and yeast. Inhibitory effect of PP is associated with pH decrease (acidic PP such as sodium acid pyrophosphate, SPP), formation of complexes with metal ions required for microbial cell division, disruption of microbial cell wall integrity and acceleration of oxidative stress. Inhibitory effect of PP is directly related to their chain length. Longer-chain length PP have superior antimicrobial capability on Gram-positive bacteria compared to shorter-chain length PP. Phosphatase enzymes naturally found in raw meat material have a ability to hydrolyze PP into shorter-chain length PP or orthophosphates. As a result of this reaction, PP may loss some of their antioxidant and antimicrobial properties. Encapsulation is very promising technology for protecting PP from enzymatic hydrolysis caused phosphatases by enrobing PP into capsules. Previous studies demonstrated that encapsulated (e) PP maintained antioxidant capabilities of PP in muscle foods. Therefore, this review study summarizes studies about utilization of ePP to improve antioxidant and antimicrobial properties of PP in meat and meat products.

Key words: *encapsulation, food quality, food safety, meat, polyphosphates.*

INTRODUCTION

The main goal of the meat industry is reducing economic losses and increasing the shelf life and storage stability of meat products by maintaining consumer health. Meat and meat products are highly susceptible to microbiological and chemical deterioration when preservation methods are not used because they are rich in essential nutrients and have high pH and water activity (Jayasena and Jo, 2013). Many methods such as the use of natural or synthetic additives, thermal processes, cooling, freezing, vacuum or modified atmosphere packaging are used in order to ensure safety and to maintain quality in meat products (Gould, 1996). As a result of the use of antimicrobial and antioxidant effective additives in meat industry, it is aimed to protect the products in terms of microbiological and chemical changes. PP are widely used food additives in meat industry due to their antimicrobial and antioxidant properties as well as they provide many beneficial effects such as improved water binding capacity and cooking yield, accelerated curing process and improved textural attributes (Gadekar et al., 2014).

PP can also be used to control the growth of microorganisms during meat processing. PP are not additives that have antimicrobial effects specifically, but are chemical components that have a suppressive effect on the growth of microorganisms under certain conditions (Moon et al., 2011). Antimicrobial effects of PP occur by changing the chemical structure of the environment by acidification, by binding metal ions such as calcium, magnesium and iron, which must be present in the environment for microbial growth, or as a synergist effect when used with certain antimicrobial additives such as nisin, ethylenediamine tetraacetic acid (EDTA) and nitrite (Maier et al., 1999; Akhtar et al., 2008). Gram-positive bacteria are more affected by PP than Gram-negative bacteria. The inhibitory effect on gram-positive bacteria depends on the chain length of the PP and the preventive effect increases with increases of chain length, and also plays a role in this effect at pH and temperature (Palmeira-de-Oliveira et al., 2011).

Lipid oxidation is a reaction that causes discoloration, formation of toxic compounds, nutrient losses and reduction of shelf life (Falowo et al., 2014). This reaction is affected by many intrinsic and extrinsic factors such as unsaturation of their fatty acids, low molecular weight metal ions, pH, oxidative enzymes, storage temperature, light, oxygen, water activity (Shahidi and Zhong, 2010). PP exhibit their antioxidant effects by binding metal ions which catalyze oxidation reaction (Kılıç et al., 2014). The antioxidative activities of PP depend on the type and concentration of used PP (Kılıç et al., 2016a). It is stated that PP such as sodium tripolyphosphate (STP), sodium acid pyrophosphate (SPP), sodium hexametaphosphate (HMP) and tetrasodium pyrophosphate (TSPP) have antioxidant effects in meat products and they show synergistic effect when used with vacuum or modified atmosphere packaging (Lee et al., 1998; Kılıç et al., 2014; Kılıç et al., 2016b; Kılıç et al., 2018). Lee (1993) indicated that tripolyphosphates form stronger complexes with metal ions (especially iron and copper) than those of pyrophosphates. A similar statement also reported by Sofos (1986). Researcher noted that the best ion-sequestering agents are long chain PP, and the ion-sequestering ability increases with increases of chain length. The powerful antioxidant effect of long chain PP can be reduced by the phosphatase enzymes before cooking (Kılıç et al., 2014). There are many studies in the literature on the antioxidative effects of phosphates. In addition, in recent studies, it is reported that this effect can be increased by using encapsulation technology (Kılıç et al., 2014; Du and Claus, 2015; Kılıç et al., 2016a; 2016b).

Encapsulation is described as a technology to entrap solids, liquids, or gaseous materials within closed capsules that can release their contents at controlled rates under certain conditions (Fang and Bhandari, 2010; Nedovic et al., 2011). Encapsulation technology in food processing contains the coating of tiny particles of food components such as flavors, sweeteners, colorants, acidulants, vitamins and enzymes (Desai and Jin, 2005). This review study is aimed to inform about usage of ePP to improve antioxidant and antimicrobial properties of PP in meat and meat products.

ANTIOXIDATIVE EFFECTIVENESS OF ENCAPSULATED POLYPHOSPHATES

Besides many beneficial effects of PP in food products, there are also numerous studies that exhibit antioxidant effects (Cheng and Ockerman, 2007; Allen and Cornforth, 2009; Kılıç et al., 2014). It has also been reported in recent studies that their effectiveness can be improved with the use of encapsulation technology (Kılıç et al., 2014; Du and Claus, 2015; Kılıç et al., 2016a; 2016b). Sickler et al. (2013a) evaluated that the effects of the use of encapsulated and unencapsulated PP (STP and SPP) in cooked ground beef patties on pH, color and oxidative changes at different storage times. According to study results, researchers stated that the lowest cooking loss and TBARS values were obtained in uSTP usage, and all PP treatments had also lower TBARS values than control samples. Sickler et al. (2013b) evaluated in another study that the impacts of uSTP (0.3% and 0.5%) and eSTP (0.3% and 0.5%), or a combination of these forms (0.3%

uSTP + 0.2% eSTP) and two different end-point cooking temperature (74ºC and 79ºC) on cooked ground turkey at different raw storage (4 h and 24 h) and post-cooked storage (0, 5 and 10 days) times. Researchers reported that eSTP reduced the TBARS by 77% (0.3% eSTP) and 80% (0.5% eSTP) in comparison to the same amount of uSTP. Kılıç et al. (2014) investigated that the effects of encapsulation technology on protecting PP from hydrolysis by phosphatases. For this purpose, researchers tested ePP (STP, HMP and SPP) at two different coating levels (30% and 50%) on lipid oxidation in ground chicken and ground beef during raw and cooked storage. Consequently, researchers noted that encapsulated or unencapsulated forms of STP and SPP were the most effective PP types in delaying lipid oxidation in both meat species. Additionally, they also stated that the coating level had no impact on the lipid oxidation inhibition level (Kılıç et al., 2014). Xie et al. (2014) investigated the impact of hydrolysis of phosphates by phosphatases on cook yield and oxidation. For this purpose, a comparison was carried out between STP, encapsulated STP and Lem-o-Fos® using a grilled beef patty model. Researchers noted that the eSTP demonstrated an enhanced antioxidant effect. Furthermore, the study results showed that the antioxidant effect provided by eSTP was more significant as the storage time increases. The effects of different end-point cooking temperatures (71ºC, 74ºC and 77ºC) on the efficiency of ePP was also investigated in another study conducted by Kılıç et al. (2015). As a result of the study, researchers stated that the application of higher end-point cooking temperature decreased TBARS values in cooked ground beef, whereas increased LPO values in cooked ground beef and chicken. Researchers suggested that using lower end-point cooking temperatures provided more benefits when using ePP (Kılıç et al., 2015). Du and Claus (2015) stated that STP, SPP and HMP are significantly effective in limiting the lipid oxidation in ground turkey, as well as PP degradation due to phosphatases are reduced by encapsulation technology. Kılıç et al. (2016a) studied to determine optimum level of ePP addition (0%, 0.1%, 0.2%, 0.3%, 0.4% and 0.5%) to enhance lipid oxidation inhibition during storage in precooked meat products. Researchers indicated that the antioxidant effect of eSTP or eSPP can be improved with increasing added ePP level in product formulation. In another study, Kılıç et al. (2016b) also investigated effects of the melting release point (60ºC and 68ºC) of the PP from ePP and heating rate (slow and fast cooking) on lipid oxidation inhibition in cooked ground meat. According to the study results, researchers noted that eSTP and eSPP were the better for inhibiting oxidative changes in cooked ground beef and chicken. Furthermore, they stated that the antioxidative effectiveness of these ePP can be improved with a higher melting release point of the encapsulation material. Claus et al. (2016) evaluated effectiveness of post-mortem pH on inhibition of lipid oxidation in raw and cooked ground turkey breasts by ePP. Researchers noted that pH difference between two sets (high, 6.4 to 6.7; low: 5.9 to 6.2) of turkey breasts had a little effect on lipid oxidation inhibition by ePP. Another study (Kılıç et al., 2018) was carried out on hamburger patty production by using the optimum coating rate, melting release point and ePP usage rates determined in previous studies mentioned above. Researchers stated that the antioxidative effectiveness of STP and SPP can be improved with 0.25% ePP usage combined with cohort uPP in patty formulation. This study showed that meat industry should consider adding 0.25% additional ePP to their product formulations in order to achieve more effective inhibiting the lipid oxidation in pre-cooked ready-to-eat meat products (Kılıç et al., 2018).

ANTIMICROBIAL EFFECTS OF ENCAPSULATED POLYPHOSPHATES

PP are additives that do not exhibit specific antimicrobial effects, but exhibit synergistic effects when used with other preventive techniques (Bunkova et al., 2014). PP exhibit potential antimicrobial effects through the following mechanisms: PP may inhibit microbial growth (1) by forming complexes with metal ions which are necessary for cell division, (2) by lowering pH with acidic PP, (3) by disrupting the cell wall integrity (4) by increasing oxidative stress and (5) by causing changes in cell morphology (Maier et al., 1999;

Cheng and Ockerman, 2007; Akhtar et al., 2008; Bunkova et al., 2014). Furthermore, PP reduce the heat resistance of the most bacteria (Luck and Jager, 1997). Many researchers are reported that the inhibitory effect on Gram-positive bacteria depends on PP chain length, and the long chain PP have a better inhibitory effect than shorter-chain PP (Zaika and Kim, 1993; Bunkova et al., 2014). Shorter-chain PP or orthophosphates are released from PP when PP are degraded by phosphatases in the meat system. Therefore, antimicrobial activity of PP may be decreased. Encapsulation is an alternative technology that can be used to protect PP from phosphatases by enrobing PP into capsules (Kılıç et al., 2014). Tenderis et al. (2020) investigated the effects of sodium lactate (SL), eSTP or eSPP forms, and their combinations on *Salmonella typhimurium*, *Escherichia coli* O157:H7 and *Staphylococcus aureus* growth in cooked ground beef during 30 days storage at 4 or 10°C. Researchers indicated that STP or SPP usage in formulation had some inhibitory effect on *S. typhimurium*, *E. coli* O157:H7 and *S. aureus* growth in cooked ground beef during 30 days storage at 4 or 10°C. In addition, researchers indicated that antimicrobial efficiency of PP is not affected by encapsulation, and the usage of PP and SL combinations have synergistic effect on reducing the growth of *S. typhimurium*, *E. coli* O157:H7 and *S. aureus* in cooked ground beef.

CONCLUSIONS

Many studies have been performed in different treatment designs to test the use and effectiveness of ePP. According to the results obtained from these studies, ePP usage can be an effective strategy to control oxidative changes in ready-to-eat meat products. In addition, ePP has not been contributed on antimicrobial activity. However, when PP are used with other antimicrobial agents, PP or ePP can demontrate synergistic effects to inhibit the growth of microorganisms.

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