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Preservation of meat products with natural antioxidants from rosemary

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Abstract. Oxidative reactions can reduce the quality of meat products. Synthetic antioxidants can delay the formation of oxidation products but their use in muscle foods has been reconsidered among modern consumers willing to purchase clean label products. Rosemary is a relevant source of antioxidants that can be explored as natural additive in muscle foods. This review aims to provide an overview of the protective effect of rosemary active against the oxidative decay in meat products. The use of rosemary essential oil or extract can slow the progression of oxidative reactions and preserve redness, reduce the accumulation of primary and secondary lipid oxidation and protein oxidation products, and slow the increase of perceived rancidity in sensory analysis. These effects were reported during the storage of patties, burgers, meatballs, sausages, and nuggets. In this sense, rosemary extracts and essential oil can be explored as natural antioxidant in meat products.

1. Introduction

The occurrence of oxidative unbalance and formation of free radicals is a major route to cause loss of quality in meat products [1]. Oxidative reactions are initiated by expose of meat products to atmospheric oxygen, UV radiation, endogenous enzymes, free radicals, and transition metals [1,2]. The absence of preventive actions and the consequent progression of oxidative reactions in susceptible components (such as myoglobin and lipids) leads to changes in quality and acceptance by consumers (color deterioration and off-odor formation) during processing and storage of meat products [1,2].

In order to delay the loss of quality derived from oxidative reactions, antioxidants have been applied in meat products [3]. Although these compounds are widely used in meat products, the concerns about the potential effects in health among consumers have been stimulating a transition towards the production of clean label products [4]. Among the several options of natural antioxidants, rosemary (*Rosmarinus officinalis* L.) stands out due to the presence of antioxidant compounds such as carnosic acid; carnosol; camphor; 1,8-cineole; and α -pinene and pleasant sensory attributes [5]. Due to the



importance of searching for natural additives for the meat industry, this review aims to discuss recent advances in the application of rosemary extracts in the protection of meat products against oxidative reactions.

2. Incorporation of rosemary active compounds in meat products

The presence of numerous antioxidant compounds with high antioxidant activity supports the evaluation of rosemary essential oil and extracts in meat products such as patties, burgers, and meatballs (Table 1). These meat products are convenient and tasty but are affected by oxidation [6–11]. In this sense, Al-Hojazeen and Al-Rawashdeh [12] evaluated two concentrations of rosemary extract in the preservation of raw and cooked chicken patties. Patties produced with either 300 or 350 ppm had lower levels of lipid and protein oxidation than control samples produced without antioxidants during 7 days at 4 °C. The instrumental and sensorially preserved redness were also better preserved in samples produced with these levels of rosemary extracts. Additionally, the intensity of rancidity was lower in these samples in comparison than control.

Table 1. Effect of rosemary antioxidants in patties, burgers, and meat balls

Meat product	Rosemary antioxidant	Storage conditions	Effect in oxidative stability	Ref
Raw and cooked chicken patties	Extract (300 and 350 ppm)	4 °C for 7 days	Reduced lipid and protein oxidation, redness loss (raw) and rancidity odor (cooked); increased sensory score of color (cooked)	[12]
Raw beef patties	Extract (0.1%; 3, 6 and 10% of carnosic acid in the extract)	4 °C for 90 days	Reduced peroxide and TBARS ^a values and loss of redness	[13]
Raw pork patties	Extract (0.1%)	4 °C for 15 days	Reduced loss of redness, metmyoglobin formation, conjugated dienes, and peroxide and TBARS values	[14]
Raw chicken patties	Extract (1%)	4 °C for 5 days	Reduced lipid oxidation and redness loss	[15]
HPP-treated raw pork patties	Active packaging with extract (4.5% of carnosic acid in film)	5 °C for 25 days	Reduced radical formation and lipid oxidation in superficial and inner section	[16]
Raw pork burger	Extract (0.1, 0.2, and 0.3%)	4 °C for 10 days	Reduced lipid and protein oxidation and redness loss (0.2%)	[17]
Raw chicken burgers	Extract (0.02%)	4°C for 21 days	Reduced lipid oxidation	[18]
Raw chicken burgers	Extract (18 and 480 mg/kg)	-18 °C for 4 months	Reduced lipid oxidation (480 mg/kg); no effect in sensory attributes	[19]
Raw mixed meat burger	Extracts (0.015, 0.03, and 0.06)	-12°C for 120 days	Low lipid oxidation and loss of redness; high acceptance among panelists	[20]
Raw beef burgers	Extract (28 mL/kg)	-18°C for 60 days	Reduced metmyoglobin formation, lipid oxidation, and redness; no effect in sensory properties	[21]
Deep-fried pork meatballs	Extract (0.02%)	-18 °C for 180 days	Reduced peroxide and TBARS values	[22]

^a TBARS: Thiobarbituric acid reactive substances

A similar experiment with raw beef patties with rosemary extract (extracts with 3, 6 and 10% of carnosic acid) and paprika oleoresin indicated lower levels of peroxides and thiobarbituric acid reactive substances (TBARS) than samples produced without antioxidants during 90 days at 4 °C [13]. The preservation of red color in patties was also observed during storage. Interestingly, the authors compared the capacity of butylhydroxyanisole (BHA) and rosemary extract to preserve the color of paprika oleoresin. The highest concentration of extract preserved the intense and characteristic red color of paprika oleoresin whereas a complete discoloration was observed in samples containing BHA after 15 days.

The combination of rosemary antioxidants with packaging systems has been providing interesting results to improve the oxidative stability of patties. This strategy was explored by Hwang et al. [14] with rosemary extract in vacuum packaged raw pork patties. The formation of metmyoglobin was reduced and a slight but significant preservation of redness was also reported by the authors. In terms of lipid oxidation, the formation of primary oxidation products (conjugated dienes and peroxides) was delayed and less intense than observed in control samples. The formation of secondary oxidation products (measured with TBARS assay) was also limited by rosemary extract in these patties. A related experiment was carried out to explore the effect of modified atmosphere packaging (63.2% O₂ and 30.6% CO₂) and rosemary extract [15]. Both lipid oxidation and loss of redness were delayed in raw chicken patties produced with rosemary during 5 days of refrigerated storage. Interestingly, this study also explored the use of plasma treatment to reduce the microbial load. Again, rosemary antioxidants reduce the intense oxidation induced by plasma treatment in patties' myoglobin and lipids.

Another relevant experiment obtained results that support the use of rosemary to preserve patties treated with non-thermal processing technologies was carried out by Bolumar et al. [16]. According to these authors, treating raw pork patties with high-pressure processing can induce the formation of free radicals and oxidation in myoglobin and lipids. The addition of rosemary extract in an active packaging reduced the formation radicals and also delayed the loss of redness and formation of lipid oxidation products during 25 days at 5 °C.

The effect of rosemary antioxidants was also reported in burgers (patties with other food additives and seasonings). For instance, Yin et al. [17] explored the effect of rosemary extract level in the preservation of raw pork burger. Using 0.2% of extract generated the lowest levels of lipid and protein oxidation during storage. Moreover, this treatment also reduced the loss of redness. A related study in raw chicken burgers stored at 4°C for 21 days indicated lower levels of lipid oxidation in comparison to control samples (without antioxidant) [18]. Similarly, Pires et al. [19] reported significant differences in the preservation of frozen stored chicken burgers (-18 °C for 4 months) with two levels of rosemary extract. The samples produced with higher level (480 mg/kg) displayed lower levels of lipid oxidation whereas no significant effects were reported in sensory analysis.

A related experiment reported a similar outcome in a burger produced with beef, chicken, and turkey meat [20]. In this case, all levels of rosemary extract reduced oxidative degradation of color and lipids during frozen storage (-12°C for 120 days). Moreover, sensory analysis also revealed that increasing the level of rosemary extract caused the sensory perception of "freshness" in this burger, which increased the acceptance from panelists. Gahruie et al. [21] reported a similar protective effect of rosemary extract during frozen storage of raw beef burgers. However, the authors indicated a significant reduction in redness.

The quality decays derived from oxidative reactions in meatballs can be delayed by rosemary antioxidants. The recent study carried out by Heś & Gramza-Michałowska [22] revealed that lipid oxidation in deep-fried pork meatballs stored for 180 days at -18 °C was reduced in relation to control samples (without antioxidant). In the same line of thought, Can et al. [23] produced an active film with rosemary extract to preserve raw chicken meatballs. According to the authors, both films (0.3 and 0.5%) were effective to reduce lipid oxidation and preserve sensory attributes and extend the shelf life by 3 days in relation to control samples (without antioxidants).

Sausages are meat products obtained from comminuted meat and animal fat with seasoning and additives (nitrate and/or nitrite) that is processed to acquire defined characteristics [24]. The wide production and consumption of this category of meat products are attributed to the vast options of

ingredients and processing conditions as well as the individual value attributed from consumers to these meat products [24]. Since these products are obtained in conditions that favor oxidative reactions (such as meat comminution, thermal processing and long periods exposed to atmospheric oxygen), the use of ingredients with antioxidant effects is a common practice. Consequently, oxidation can occur and lead to the formation volatile products and sensory-active compounds that compose the expected odor and flavor of these meat products [25–28]. In this case, nitrite (added as sodium salt or produced during fermentation stage) has a central role to prevent quality decay from oxidative reactions [29]. Replacing nitrate/nitrite is current major challenge in the meat industry due to the absence of an adequate replacer with similar or higher capacity to inhibit oxidative reactions and also assist in the physicochemical and microbial stability and safety [29,30].

Alternatively, rosemary essential oil and extracts have been proposed as natural antioxidant to improve the oxidative stability of sausages (Table 2). For instance, Abbasi et al. [31] observed that rosemary essential oil reduced the formation of lipid oxidation products in a cooked cured chicken sausage in relation to the control with nitrite salt. These authors also observed that redness was reduced but there was no effect on sensory attributes between rosemary and control sausage. In a similar experiment, Zhou et al. [32] observed a concentration-dependent effect of rosemary extract on the quality of a cooked pork sausage. Increasing rosemary concentration (especially in the range 0.3-0.5%) reduced the formation of oxidation products and increased redness in relation to control with nitrite. Additionally, minor changes in other physicochemical attributes were also reported by these authors.

Table 2. Effect of rosemary antioxidants in sausages and nuggets

Meat product	Rosemary antioxidant	Storage conditions	Effect on oxidative stability	Ref
Cooked cured chicken sausage	Essential oil (5%)	Final product	Lower redness and lipid oxidation; no effect in sensory attributes	[31]
Cooked and smoked pork sausage	Extract (0.1, 0.2, 0.3, 0.4, and 0.5%)	Final product	Reduced oxidative state; increased redness (0.3-0.5%)	[32]
Cooked and smoked pork sausage	Extract (0.1, 0.2, 0.3, 0.4, and 0.5%)	Stored at 4 °C for 20 days	Increased redness, reduced lipid oxidation and VBN ^a (0.5%)	[33]
Cooked cured beef sausage	Extract (250 mg/kg)	Stored at 4 °C for 25 days	Lower peroxide value and TBARS ^b values	[34]
Fermented pork sausages	Extract (0.48%; 100 g/kg rosemary extract in the oil phase)	Stored at 7 and 20 °C for 49 days	Reduced POV ^c , TBARS and hexanal content, redness loss, and rancidity (sensory analysis)	[35]
Chicken nuggets	Extract (150 ppm of carnosic acid and carnosol)	Stored at -18 °C for 9 months	Reduced lipid oxidation; no effect in color, and rancidity odor and taste	[36]
Caiman nuggets	Extract (0.05%)	Stored at -18 °C for 120 days	Preserved redness, reduce lipid oxidation; no effect in sensory attributes	[37]

^a VBN: Volatile basic nitrogen

^b TBARS: Thiobarbituric acid reactive substances

^c POV: Peroxide value.

In a later experiment from the same research group, the protective effect of rosemary extract was evaluated during the refrigerated storage of a cooked and smoked pork sausage [33]. Again, rosemary extract exerted a concentration-dependent effect to inhibit the formation of lipid oxidation products and the formation of volatile basic nitrogen (VBN) during 20 days at 4 °C, principally in 0.5% treatment. Redness increased with rosemary concentration and was stable throughout the storage period. Likewise, rosemary extract reduced the peroxide and TBARS values in a cooked cured beef sausage during 25 days of storage at 4 °C. The experiment, carried out by Erdmann et al. [35], also highlighted the antioxidant effect in fermented sausages. In this case, the authors studied the influence of an emulsion system containing rosemary extract to delay oxidation during storage in *Chouriço*, a traditional Portuguese sausage produced with pork meat. According to the authors, the sausages produced with rosemary extract displayed lower lipid oxidation levels (peroxide and TBARS values and hexanal content), loss of redness and perceived rancidity in sensory analysis in relation to control. It is also relevant to mention that rosemary extract can exert antioxidant activity regardless of nitrite presence and no pro-oxidant effects were reported in any of the aforementioned studies.

Another relevant meat product susceptible to oxidative reactions is nuggets. These meat products are obtained from minced meat and covered with layers known as pre-dust (usually composed of wheat flour), batter (can be prepared with cold water with corn starch and flour), and breading (breadcrumbs). Then, shaped nuggets are pre-fried (> 165 °C for a short period of time) and frozen [38,39]. Differently to other meat products discussed above, nuggets are deep-fried (usually in unsaturated vegetable oils), which causes the absorption of the frying oil and so can favor oxidative reactions during frozen storage [40]. The use of rosemary extract can improve the oxidative stability of nuggets. This statement is supported by the study carried out by Teruel et al. [36]. The natural extract in three forms (liquid ethanol, liquid acetone, and powder acetone) reduced lipid oxidation during 9 months of frozen storage in comparison to control without antioxidants. However, no differences were reported for color, rancid odor and taste between rosemary and control nuggets. In the same line of thought, Paiva et al. [37] evaluated the effect of rosemary extract in caiman nuggets. Lipid oxidation was reduced and a better preservation of redness during frozen storage was reported by these authors. No significant effect in sensory attributes was reported among treatments.

3. Conclusion

Delaying the progression of oxidative reactions is an essential action to preserve the quality in meat products. Antioxidants naturally found in rosemary can be of great value to obtain meat products with enhanced oxidative stability and increased shelf life. The antioxidant effect of rosemary is observed in the use of both essential oils and extracts regardless of meat product (patties, burgers, meatballs, sausages, or nuggets), presence of other additives and ingredients and preservation technologies (packaging systems). The protection against oxidative reactions induced by innovative and non-thermal technologies (plasma and high-pressure processing) is also observed. Therefore, rosemary antioxidants can be of great value in the production of these muscle foods. Future studies with rosemary antioxidants could explore their application in production of healthier and functional meat products.

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