

Combined Use of Black Barberry (*Berberis crataegina* L.) Extract and Nitrite in Cooked Beef Sausages during the Refrigerated Storage

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ABSTRACT

Effects of combined use of black barberry (*Berberis crataegina* L.) extract and sodium nitrite on the quality and shelf life of cooked beef sausages were investigated. Different concentrations of the extract (30, 60 and 90 mg kg⁻¹) in combination with nitrite (30, 60 and 90 mg kg⁻¹) were added to sausage formulations. Total viable counts, pH, proximate analysis, residual nitrite level, lipid oxidation, color and sensory data were studied against the blank and control samples during the storage for 30 days at 4°C. A gradual decrease in the nitrite level was observed during the storage for all samples studied. Samples using the extract from this study showed similar redness but lower lightness when compared to the control sausage sample with 120 mg kg⁻¹ sodium nitrite. Sensory evaluation of the samples indicated similar results to those of the control. Accordingly, there is a potential benefit for partial replacement of sodium nitrite with barberry extract in the cured meat products.

Keyword: Antibacterial activity, Antioxidant, Refrigeration, Shelf-life, Sensory.

INTRODUCTION

Curing agents including NaNO₂ and KNO₂ are widely used in meat products to develop the characteristic flavor and the red meat color, to inhibit growth and toxin production of poisoning anaerobic microorganisms such as *Clostridium botulinum* and to delay spoilage and oxidative rancidity (Pourazrang *et al.*, 2002; Zanardi *et al.*, 2002).

According to FDA legislation for additives and preservatives in meat products, concentration of sodium or potassium nitrite should not exceed 120 mg kg⁻¹ in the final product. Intake of high amount of nitrite presents human health

risks including metamyoglobin production as well as vasodilator and allergenic effects (Cammack *et al.*, 1999). Nitrous acid produced from NaNO₂ may react with secondary amines and amino acids of meat products and form N-nitroso compounds, e.g. nitrosamines, that show mutagenic, toxic, nephrotoxic, neurotoxic, and carcinogenic effects (Karl-Otto, 2008; Rywotycki, 2002). Therefore, there has been a growing interest to reduce or eliminate nitrite in the food products. Due to the antioxidant, and antimicrobial properties of many herbs, plants, fruits, and vegetables, they are excellent candidates for preservatives (Dowlati *et al.*, 2015; Maaroufi *et al.*, 2015; Mazidi *et al.*, 2015).

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al., 2012; Mousavinejad *et al.*, 2015). Many natural ingredients such as citrus fruits by-products (Fernandez-Lopez *et al.*, 2004), green tea (Bozkurt, 2006), grape seed (Brannan, 2009; Lau and King, 2003), rosemary and oregano (Hernández-Hernández *et al.*, 2009) have been considered as preservatives. In the past few years, various plant materials containing natural preservatives such as phenolic compounds have demonstrated antioxidant and antimicrobial activities in the sausage (Coutinho de Oliveira *et al.*, 2012; Sallam, *et al.*, 2004; Viuda-Martos *et al.*, 2010). Black barberry (*Berberis crataegina*) belongs to the family Berberidaceae. This plant is used worldwide in traditional medicine (DeveliIsikh and Yilmaz, 2011). Fruits of *Berberis sp.* are rich in vitamin C, anthocyanins and other phenolic compounds (Wallace and Giusti, 2008; Akbulut *et al.*, 2009; Parichehr and Golkho, 2009; Gulsoy and Ozkan, 2011). *Berberis sp.* extracts have good antioxidant and antimicrobial activities (Mollaei *et al.*, 2010; Gulsoy and Ozkan, 2011). This is due to the anthocyanins and other phenolic compounds present in such extracts (Konczak and Zhang, 2004). To the best of the authors' knowledge, black barberry has not been reported in any food products as additives. This study is the first communication on the combined use of barberry extract and sodium nitrite in a cured meat product. We aimed to investigate the effects of combined use of black barberry (*Berberis crataegina*) extract and sodium nitrite on the quality and shelf-life of cooked beef sausages.

MATERIALS AND METHODS

Plant Material and the Extraction Procedure

Black barberry was purchased from a local market and dried in a dark place at room temperature. Dried fruits were ground

using a dry grinder and stored in sealed multi-lamellar bags at -20°C. The sample was mixed with enough amount of petroleum ether (40-60 grade) and stirred at 250 rpm in an orbital shaker for 12 hours at room temperature. After solvent removal, the sample was dried using medium air flow. The samples were then suspended in ethanol (0.1%, v/v) and stirred at 150 rpm in orbital shaker for 24 hours at room temperature. After filtration (using Whatman No.1 filter paper), the residual solvent was removed at 40°C using a rotary evaporator. Collected dried extract was stored at 4°C in a dark place until use (Mollaei *et al.*, 2010).

Preparation of Beef Sausage

Eleven sausage samples (S1 to S9, control and blank) were prepared according to the formulations specified in Table 1. The sausage samples manufactured in 5-kg batches according to the formulations: beef (3.1 kg), ice (0.92 kg), soybean oil (0.7 kg), NaCl (0.08 kg), starch (0.14 kg), soybean isolate (0.09 kg), Na₅P₃O₁₀ (0.02 kg), ascorbic acid (0.01 kg), and spice blend (0.05 kg, Bratwurst, A.C. Legg, USA). The cooked beef sausages were made in the

Table 1. Sample identities and the levels of barberry extract and sodium nitrite added to the sausage samples in this study (3 replicates).

Samples	Nitrite level (mg kg ⁻¹)	Barberry extract (mg kg ⁻¹)
Control	120	-
Blank	-	-
S1	30	30
S2	30	60
S3	30	90
S4	60	30
S5	60	60
S6	60	90
S7	90	30
S8	90	60
S9	90	90

R and D department of Solico Meat Product Company (Tehran, Iran). Beef, salt, $\text{Na}_5\text{P}_3\text{O}_{10}$ and NaNO_2 were placed in a cutter (Seydelmann, Aalen, Germany) and mixed for approximately 1 minute. Fifty percent of the ice and spice blends were then added and mixed at a high speed. After that, the speed of the cutter was reduced and soybean oil was added and mixed for 5 minutes. The remaining 50% of the ice, starch, ascorbic acid and extract (at different levels according to Table 1) were added and mixed. Each sample was prepared in a polyamide package and cooked at 75°C for 1 hour. Finally, the samples were cooled with water and stored at 4°C for 30 days.

Compositional Analysis of Sausage Samples

Fat, protein, moisture, and ash contents of sausage samples were determined in day 1, according to Association of Official Analytical Chemist method (AOAC, 2002a, b, c, d). In order to measure the pH values, 10.0 g of ground samples were mixed with 90 mL distilled water for 1 minute. The measurement was then performed by using a digital pH-meter (Model GIp22, Crison, Barcelona, Spain).

Nitrite Content

Nitrite contents of the sausage samples were determined using a reference method (ISO No 2918/75, ISO, 1975). Briefly, 10 grams of ground sausage samples were mixed with 5 mL borax and 100 mL warm (80°C) distilled water. After cooling the samples to the room temperature, 2 mL of potassium ferrocyanide trihydrate solution (10.6%) and 2 mL of zinc acetate dihydrate solution (2.2 g zinc acetate dihydrate and 3 mL acetic acid in 100 mL distilled water) were added to the mixture and left at room temperature for 30 minutes. The mixture was filtered with Watman no. 1 filter paper and then 10 mL of the filtrate was mixed

with 10 mL of sulfanilamide solution (2.0 g sulfanilamide and 100 mg sulphuric acid in 1,000 mL distilled water) and 6 mL of HCl 45%. After 5 minutes, 2 mL of N-(1- α -naphthyl) ethylenediamine dihydrochloride solution 0.1% was added and placed in a dark room for 10 minutes. Absorbance measurements were then made at 538 nm using a spectrophotometer (2100 spectrophotometer, Unico, China). Nitrite concentrations were determined according to the equation $Y = 9.49X + 0.096$ with Y representing the nitrite concentration (mg kg^{-1}), and X representing the absorbance values at 538 nm.

Microbial Analysis

After peeling the sausage samples, 10 g was cut aseptically into slices in a sterile container and homogenized with 90 mL of sterile 0.1% peptone water for 2 minutes in a stomacher (Lab blender 400, Seward Medical, London, UK). Then, appropriate decimal dilutions were made from the resultant solution using first diluents (10^{-1}) and plated in duplicate for the following measurements. Total Viable Counts (TVC) were enumerated by the pour-plate method using plate count agar (Merck, Darmstadt, Germany). Plates of TVC were incubated at 30°C for 3 days (ISO 4833: 2003). *C. perfringens* enumeration was performed using an anaerobic culture in sulfite polymyxin sulfadiazine agar (SDS agar, Merck, Darmstadt, Germany) (Yetim *et al.*, 2006).

Determination of Antioxidant Activities

The antioxidant activities of the samples were determined using 2, 2'-DiPhenyl-1-PicrylHydrazyl (DPPH) reagent according to the procedure described by Viuda-Martos *et al.* (2009). Samples (0.1 g each) were mixed vigorously with ethanol (4 mL) for 2 minutes. Then, 2 mL of 250 $\mu\text{mol L}^{-1}$ DPPH solution was mixed with 2 mL of the extract



solution for 1 min and placed in a dark room for 30 minutes. Absorbance measurements were taken at 517 nm. Inhibition activities of the samples against DPPH free radical was then determined according to the following expression:

$$\text{Inhibition ratio (\%)} = [(A_{\text{blank}} - A_{\text{sample}}) / A_{\text{blank}}] \times 100$$

Where, A_{blank} is the absorbance of the control reaction (containing all the reagents except the test sample) and A_{sample} is the absorbance measured for the test sample. The ThioBarbituric Acid Reactive Substances (TBARS) of the samples were measured after 2, 9, 16, 23 and 30 days of storage according to the method reported by Pfalzgraf *et al.* (1995). Ten grams of the sample was homogenized with 20 mL of 10% (w/v) trichloroacetic acid using an ultra-Turrax (90 seconds, 20,000 rpm). The homogenate was centrifuged and the supernatant was filtrated through a paper filter (Watman NO. 1). Two mL of the filtrate was mixed with 2 mL of the TBA (2-thiobarbituric acid) reagent (300 mg TBA in 100 mL water). The mixture was heated on a water bath at 97°C for 20 minutes. After cooling the mixture to the ambient temperature, the absorption was measured at 532 nm. TBARS values were expressed as mg of malondialdehyde per kg sample using 1, 1, 3, 3-tetraethoxypropane as standard.

Color Measurements

After microbiological and chemical composition measurements, the samples with lowest TBARS value and also microbial content were selected for determining the color stability during the 30 days of storage at 4°C. Color determination was made by using a Hunter-Lab Color-flex colorimeter (Hunter Associated Lab, Inc., Reston, VA) against a white standard. Each sample was measured at four different locations on the surface and an average score was reported. CIE Lab coordinates were reported as

Lightness (L^*), redness (a^*) and yellowness (b^*).

Sensory Evaluation

The samples with the best results from microbiological and chemical attributes were selected for the sensory analysis. Sensory evaluation (flavor, odor and overall acceptability) of the samples were performed using a nine-point hedonic scale (9= Like extremely; 8= Like very much; 7= Like moderately; 6= Like slightly; 5= Neither like nor dislike; 4= Dislike slightly; 3= Dislike moderately; 2= Dislike very much, and 1=Dislike extremely) in day 1. During the sensory evaluation, samples were shared in the sensory room of Sari Agricultural University's laboratory where no foreign smell was present. The product was defined as unacceptable (a score < 5). The panel consisted of 15 trained individuals in the Food Science and Technology Department of Sari Agricultural University.

Statistical Analysis

All experiments were carried out in triplicate and the data were analyzed by SPSS 18 for Windows to assess the significance of the treatments. Analysis Of Variance (One way ANOVA) was conducted and means were compared using Duncan's multiple-range test applying a 95% confidence level.

RESULTS AND DISCUSSION

Compositional Properties of the Cooked Beef Sausages

Protein, fat, ash, and moisture contents of all samples on the first day after production are shown in Table 2. Statistical analysis of the data did not show any significant differences among the samples with the different levels of added nitrite and black

Table 2. Proximate analysis of cooked beef sausages (3 replicates) during the 30 days of storage at 4°C.

Samples ^a	Composition (% w/w)			
	Protein	Fat	Moisture	Ash ^b
S1	13.3 ± 0.4	23.5 ± 1.1	61.1 ± 0.0	2.2 ± 0.0 ^c
S2	13.3 ± 0.8	22.8 ± 1.8	61.5 ± 0.0	2.4 ± 0.0 ^{abc}
S3	13.4 ± 0.2	23.5 ± 0.4	60.6 ± 0.4	2.5 ± 0.0 ^a
S4	13.1 ± 1.1	23.3 ± 0.4	61.3 ± 2.2	2.3 ± 0.0 ^{cd}
S5	13.4 ± 0.5	23.5 ± 1.8	60.8 ± 1.2	2.3 ± 0.0 ^{cd}
S6	13.8 ± 0.1	23.6 ± 2.2	60.2 ± 0.8	2.4 ± 0.0 ^{abc}
S7	13.3 ± 0.9	22.4 ± 1.5	60.9 ± 1.3	2.3 ± 0.0 ^{bcd}
S8	13.4 ± 1.2	23.8 ± 0.5	60.4 ± 2.2	2.4 ± 0.0 ^{abc}
S9	13.3 ± 0.4	24.0 ± 0.4	60.3 ± 0.5	2.4 ± 0.0 ^{abc}
Control	13.4 ± 0.7	24.1 ± 0.8	60.2 ± 1.3	2.3 ± 0.1 ^{bcd}
Blank	12.9 ± 1.4	23.9 ± 2.4	61.1 ± 0.4	2.1 ± 0.1 ^f

^a Sample symbols are defined in Table 1. ^b In each column, means identified with different letters are significantly different (P < 0.05).

barberry extract but blank had lower ash level than the other samples (P < 0.05).

Changes in the Residual Nitrite Content

Measured nitrite contents of the samples of this study during the 30 days of storage are shown in Table 3. Higher concentrations of added nitrite resulted in higher amounts of residual nitrite in the product. These results are in agreement with the findings of

Perez-Rodriguez *et al.* (1996) and Fernandez-Lopez (2007) in cured sausages. The nitrite contents of the samples decreased gradually during the 30 days of storage due to the conversion of nitrites into nitric oxide. Hustad *et al.* (1973) reported significant impacts of both storage time and temperature on the nitrite concentration. Since storage temperature was held constant in this study, storage time can be considered as the main factor influencing the nitrite

Table 3. Residual nitrite levels (mg per kg sausage) in the samples (3 replicates) during the 30 days of storage at 4°C.^a

Samples ^b	Storage period (Days)				
	2	9	16	23	30
S1	12.9±1.4 ^{d1}	11.8±1.1 ^{bc1}	8.7±0.9 ^{c2}	6.7±1.1 ^{d23}	5.0±0.4 ^{dc3}
S2	12.1±1.1 ^{d1}	11.4±1.2 ^{d1}	8.1±1.3 ^{c2}	6.5±0.2 ^{d23}	4.9±0.6 ^{dc3}
S3	13.39±0.9 ^{d1}	11.3±1.7 ^{d1}	7.1±0.7 ^{c3}	6.2±0.3 ^{d2}	4.7±0.1 ^{d2}
S4	26.4±2.9 ^{c1}	19.9±0.5 ^{b2}	13.6±1.3 ^{c3}	10.1±0.4 ^{c34}	8.2±0.2 ^{c4}
S5	25.2±2.7 ^{c1}	18.9±0.4 ^{b2}	13.2±1.4 ^{c3}	10.0±0.7 ^{c34}	7.9±0.3 ^{dc4}
S6	22.3±3.3 ^{c1}	17.6±0.9 ^{bc1}	12.4±2.0 ^{c2}	9.5±0.9 ^{c23}	7.4±0.5 ^{dc3}
S7	46.0±4.5 ^{b1}	32.9±2.1 ^{a2}	25.8±3.5 ^{b3}	20.5±1.0 ^{b34}	16.2±0.4 ^{b4}
S8	43.3±1.4 ^{b1}	32.6±2.7 ^{a2}	25.9±4.4 ^{b3}	20.0±0.9 ^{b34}	15.8±0.5 ^{b4}
S9	42.9±1.4 ^{b1}	31.6±1.0 ^{a2}	24.7±2.3 ^{b3}	19.6±0.6 ^{b4}	15.1±0.7 ^{b5}
Control	68.9±1.4 ^{a1}	54.1±7.1 ^{a12}	39.0±10.2 ^{a23}	31.3±1.1 ^{a34}	23.4±4.1 ^{a4}
Blank	0.0	0.0	0.0	0.0	0.0

^a In each column, means identified with different letters are significantly different (P < 0.05). In each row, means identified with different numbers are significantly different (P < 0.05). ^b Sample symbols are defined in Table 1.



concentration. Nitrites in the meat form nitric oxide, which reacts with heme compounds in the meat and form nitrosomyoglobin, the pigment responsible for the pink color of cured meats (Gotterup *et al.*, 2008). The nitrite content of the control sample was found at 69 mg kg⁻¹ at the beginning of storage period (day 2) while it was reduced to 39 mg kg⁻¹ after 16 days of storage. At the end of the storage period (30 days), the nitrite content was reduced to 23 mg kg⁻¹. These results confirmed the findings reported by Cassens (1997) that nitrite level declines during the storage.

Changes in the Microbial Aspects of Cooked Beef Sausages

Changes in the total viable counts of the cooked beef sausages during the 30 days of storage at 4°C are shown in Table 4. The growth of microorganisms in the blank was more pronounced ($P < 0.05$) than in the samples with added barberry extract and nitrite at all times. At the end of the storage period, samples S3 and S6 containing the highest levels of barberry extract showed the

lowest TVC. Based on the results of the current study, combination of low moisture content, a pH value of around 6.0, and the cooking as well as the storage at 4°C seems to be sufficient to produce a microbiologically stable product for at least 30 days of storage. In most samples, TVC (aerobic) of the bacteria at the end of the storage period was lower than what is considered for a degraded product ($< 5 \log \text{cfu g}^{-1}$) (ISIRI, 2010). No indication of *C. perfringens* was found in the samples used in the current study. As is the case for lipid oxidation, the antimicrobial activity of barberry extracts might be attributed to the bioactive compounds, especially phenolic compounds and alkaloids that are present in them (Mollaei *et al.*, 2010). Also, the effectiveness of antioxidant compounds depends on their corresponding pH values (Li *et al.*, 2009). pH values of the cooked sausages from the current study increased gradually during the storage at 4°C (Table 5). This is probably due to the microbial production of basic compounds such as ammonia (Nychas *et al.*, 1998) in the product. The values of pH for the control and those for the samples with different concentrations of barberry extracts were

Table 4. Total viable counts ($\log_{10}\text{cfu/g}$) of the cooked beef sausages (3 replicates) during the 30 days of storage at 4°C.^a

Samples ^b	Storage period (Days)				
	2	9	16	23	30
S1	2.4±0.3 ^{ab1}	3.42±0.29 ^{ab2}	3.93±0.37 ^{ab23}	4.69±0.45 ^{ab3}	5.83±0.23 ^{a4}
S2	2.4±0.5 ^{ab1}	3.12±0.50 ^{abc12}	3.79±0.36 ^{abc2}	4.36±0.39 ^{abc23}	5.34±0.54 ^{ab3}
S3	2.2±0.3 ^{b1}	2.46±0.37 ^{cb1}	2.95±0.27 ^{c12}	3.45±0.43 ^{c23}	4.16±0.28 ^{d3}
S4	2.4±0.4 ^{ab1}	3.02±0.66 ^{abc12}	3.53±0.30 ^{abc12}	4.12±0.51 ^{abc23}	5.10±0.40 ^{ab3}
S5	2.6±0.5 ^{ab1}	3.10±21 ^{abc12}	3.48±0.23 ^{bc12}	3.93±0.47 ^{abc2}	4.89±0.51 ^{dc3}
S6	2.2±0.2 ^{b1}	2.24±0.13 ^{a1}	2.92±0.11 ^{a2}	3.32±0.38 ^{c2}	4.08±0.24 ^{d3}
S7	2.4±0.3 ^{ab1}	3.01±0.26 ^{abc12}	3.32±0.48 ^{abc12}	4.13±0.44 ^{abc2}	5.31±0.25 ^{ab3}
S8	2.3±0.6 ^{ab1}	2.98±0.28 ^{abc1}	3.26±0.41 ^{bc12}	4.08±0.50 ^{abc2}	5.19±0.29 ^{ab3}
S9	2.6±0.4 ^{ab1}	3.03±0.65 ^{abc12}	3.29±0.57 ^{abc12}	4.21±0.73 ^{abc2}	4.95±0.26 ^{bc3}
Control	2.1±0.2 ^{ab1}	2.49±0.34 ^{bc1}	3.16±0.26 ^{bc2}	3.75±0.48 ^{bc2}	4.64±0.29 ^{bc3}
Blank	3.2±0.3 ^{a1}	3.74±0.18 ^{a12}	4.18±0.55 ^{a2}	5.17±0.58 ^{a3}	6.76±0.41 ^{a4}

^a In each column, means identified with different letters are significantly different ($P < 0.05$). In each row, means identified with different numbers are significantly different ($P < 0.05$). ^b Sample symbols are defined in Table 1.

Table 5. pH values for the cooked beef sausages (3 replicates) during the 30 days of storage at 4°C.^a

Samples ^b	Storage period (days)				
	2	9	16	23	30
S1	6.18 ± 0.03 ^{ab3}	6.29 ± 0.01 ^{a2}	6.37 ± 0.01 ^{c2}	6.34 ± 0.10 ^{dc2}	6.55 ± 0.04 ^{b1}
S2	6.17 ± 0.01 ^{ab3}	6.32 ± 0.02 ^{a2}	6.35 ± 0.01 ^{ab2}	6.34 ± 0.00 ^{dc2}	6.50 ± 0.08 ^{cb1}
S3	6.13 ± 0.02 ^{b3}	6.31 ± 0.02 ^{a2}	6.32 ± 0.01 ^{a2}	6.29 ± 0.06 ^{d2}	6.43 ± 0.04 ^{a1}
S4	6.19 ± 0.03 ^{ab3}	6.35 ± 0.05 ^{a2}	6.34 ± 0.02 ^{ab2}	6.36 ± 0.04 ^{bc2}	6.47 ± 0.05 ^{bc1}
S5	6.20 ± 0.06 ^{a3}	6.32 ± 0.02 ^{a12}	6.36 ± 0.03 ^{b2}	6.31 ± 0.01 ^{dc12}	6.49 ± 0.04 ^{bc1}
S6	6.18 ± 0.03 ^{ab3}	6.35 ± 0.05 ^{a2}	6.31 ± 0.01 ^{ab2}	6.32 ± 0.07 ^{dc2}	6.44 ± 0.10 ^{bc1}
S7	6.23 ± 0.02 ^{a3}	6.36 ± 0.08 ^{a2}	6.34 ± 0.04 ^{ab2}	6.35 ± 0.06 ^{bc2}	6.51 ± 0.04 ^{bc1}
S8	6.21 ± 0.03 ^{ab4}	6.29 ± 0.07 ^{a2}	6.33 ± 0.02 ^{ab2}	6.33 ± 0.09 ^{dc2}	6.51 ± 0.07 ^{bc1}
S9	6.16 ± 0.01 ^{ab4}	6.31 ± 0.02 ^{a3}	6.30 ± 0.06 ^{ab3}	6.38 ± 0.03 ^{bc2}	6.52 ± 0.10 ^{bc1}
Control	6.18 ± 0.03 ^{ab3}	6.33 ± 0.03 ^{a2}	6.37 ± 0.02 ^{ab2}	6.41 ± 0.04 ^{b2}	6.47 ± 0.00 ^{bc1}
Blank	6.19 ± 0.03 ^{ab5}	6.35 ± 0.02 ^{a4}	6.44 ± 0.02 ^{a3}	6.56 ± 0.03 ^{a2}	6.71 ± 0.01 ^{a1}

^a In each column, means identified with different letters are significantly different (P<0.05). In each row, means identified with different numbers are significantly different (P<0.05). ^b Sample symbols are defined in Table 1.

similar in the current study.

Treatments Effects on Antioxidant Properties of the Sausages

Figure 1 shows the effects of barberry extract and added sodium nitrite on the antioxidant properties (DPPH inhibition ratio) of the cooked sausage samples stored at 4°C for 30 days. On the second day of storage, samples with different levels of barberry extract showed higher antioxidant activities than that of the blank. Increasing the extract level in the product (from 30 to 90 mg kg⁻¹) also resulted in an increase in

the antioxidant activities of the sausage samples (Figure 1). However, they declined in most samples during the storage. Samples with the highest amount of nitrite (90 mg kg⁻¹) indicated less antioxidant activities than those with 30 and 60 mg kg⁻¹ nitrite. This could be explained by possible interaction between the nitrite and the phenolic compounds present in the barberry extract (Coutinho de Oliveira *et al.*, 2012). Similar pattern was found in the changes in the TBARS values of the samples studied here during the 30 days of storage (Figure 2). Higher TBARS value for the blank sample indicated that lipid oxidation in this sample was at higher level than those of the other

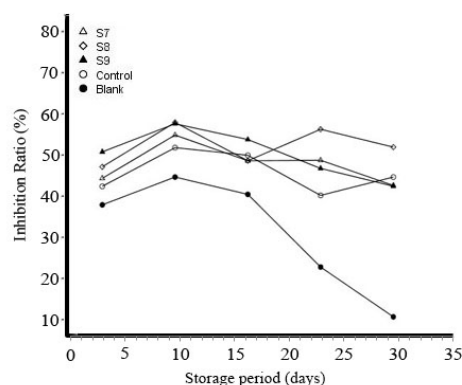
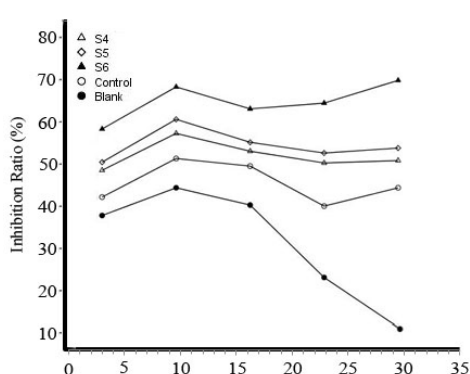


Figure 1. Effects of combined use of barberry extract and sodium nitrite on the antioxidant properties (DPPH inhibition) of the cooked beef sausages stored at 4°C for 30 days (sample identities are given in Table 1).

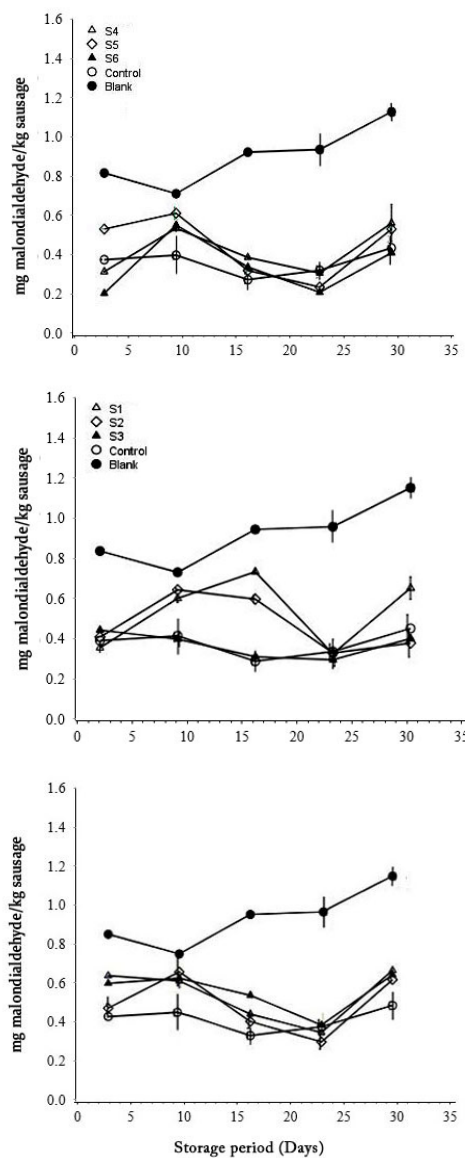


Figure 2. Effects of combined use of barberry extract and sodium nitrite on the TBARS values (mg malondialdehyde kg⁻¹) of the cooked beef sausage samples stored at 4°C for 30 days (sample identities are given in Table 1).

samples. Slight differences were found in the TBARS values of the samples with different levels of barberry extract and added nitrite. These results demonstrate the potential antioxidant effect of black barberry extract due to the presence of natural antioxidants (Gulsoy and Ozkan, 2011). According to Lücke (2000), nitrite

concentration required for a clear antioxidant effect in different meat products can vary within 20-50 mg kg⁻¹. The maximum allowed level of TBARS value for meat products is about 1 mg malondialdehyde/kg sample (Ockerman, 1976). In the current study, all the samples using nitrite and barberry extract indicated TBARS values below 0.71 mg malondialdehyde kg⁻¹ sample and, therefore, they are acceptable as food products. The TBARS values for the samples indicated a decreasing trend from day 9 to day 23 due to a possible malondialdehyde bio-decomposition (Smith and Alford, 1968; Moerck and Ball, 1974), malondialdehyde reactions with proteins and sugars or further oxidation of malondialdehyde to other products such as alcohols and acids (Fernández, *et al.*, 1997). Melton (1983) stated that despite the fact that malondialdehyde is a secondary oxidation product; there is no reason for its increase toward the end of storage period. Typically, TBARS values decreased with increasing the concentration of barberry extract in the current study. Although treatment with sodium nitrite and barberry extract resulted in significant inhibition of lipid oxidation (P<0.05), the antioxidant effect was only synergistic with the combined effect of 90 mg kg⁻¹ extract and 30 mg kg⁻¹ nitrite. This combination showed lower (P< 0.05) TBARS values than those of other combinations after 30 days of storage. Use of 90 mg kg⁻¹ nitrite and barberry extract (combined) helped prevent the lipid oxidation in the current study. However, an antagonistic effect was observed in the samples with 90 mg kg⁻¹ barberry extract, which suggests a possible interaction between nitrite and chemical compounds present in the barberry extract. Also, Coutinho de Oliveira *et al* (2012) observed that the highest levels of *Satureja Montana* essential oil and nitrite had antagonistic effect on mortadella.

Treatments Effect on the Color Profile of the Sausages

After microbiological analysis and chemical composition measurements, S3, S6, S9, control and blank samples were chosen for determining the color stability during 30 days of storage at 4°C. These changes as well as those of the control and the blank samples are shown in Table 6. On the second day of storage (the day after production), samples S3, S6 and S9 had smaller L^* values than the control. This may have been caused by the addition of barberry extract, which presented a dark red color. No significant changes in the Lightness values (L^*) were observed during the 30 days of storage for S3, S6, S9 and the control ($P < 0.05$). However, the L^* value of the blank decreased during the storage, which may be attributed to the moisture loss. Considering the redness (a^* value, the second color attribute investigated in this study), no significant ($P < 0.05$) differences

were observed among S3, S6 and the control samples on day 2 of storage. S9, with 90 mg kg^{-1} sodium nitrite, indicated the lowest a^* value compared to S3 and S6 due to higher TBARS values at the end of the storage (0.59, 0.39 and 0.42 mg malondialdehyde kg^{-1} , for S9, S3 and S6, respectively, Figure 2). S3 did not indicate any changes in the redness during the 30 days of storage period, but, S9, the control, and blank samples showed significant reductions during this period. Fernandez-Gines *et al.* (2003) and Terns *et al.* (2011) also observed a similar behavior in the a^* values of sausage throughout the storage. According to Lynch and Faustman (2000), the decline in the intensity of the red color during the storage could be explained by the interdependence between the lipid oxidation and color oxidation in the meats. Pigment oxidation may catalyze lipid oxidation and the free radicals produced during the oxidation may oxidize iron or denature the myoglobin molecules impacting negatively the color of

Table 6. Color attributes (L^* , a^* and b^*) of the selected sausage samples (3 replicates) from this study during the 30 days of storage at 4°C.^a

Parameters	Samples ^b	Storage period (Days)				
		2	9	16	23	30
L^*	S3	65.8 ± 1.1 ^{c1}	64.2 ± 0.9 ^{b1}	66.0 ± 1.4 ^{b1}	64.8 ± 1.2 ^{b1}	64.1 ± 0.9 ^{b1}
	S6	64.5 ± 0.6 ^{c1}	64.1 ± 0.7 ^{b1}	64.7 ± 1.2 ^{b1}	64.8 ± 0.6 ^{b1}	63.8 ± 1.5 ^{b1}
	S9	64.8 ± 0.4 ^{c1}	64.7 ± 0.3 ^{b1}	65.4 ± 0.6 ^{b1}	64.9 ± 1.8 ^{b1}	63.9 ± 0.4 ^{b1}
	Control	71.7 ± 0.2 ^{a1}	70.4 ± 1.1 ^{a1}	71.9 ± 0.3 ^{a1}	69.8 ± 1.4 ^{a1}	69.1 ± 2.1 ^{a1}
	Blank	57.1 ± 0.4 ^{c1}	54.0 ± 0.84 ^{c2}	52.1 ± 0.2 ^{c3}	49.7 ± 0.7 ^{c2}	47.9 ± 1.1 ^{c2}
	a^*	S3	9.3 ± 0.9 ^{a1}	9.9 ± 0.2 ^{a1}	9.4 ± 0.1 ^{b1}	9.4 ± 0.0 ^{ab1}
S6		9.4 ± 0.1 ^{a1}	9.3 ± 0.4 ^{a1}	9.8 ± 0.3 ^{a12}	9.7 ± 0.2 ^{a12}	10.1 ± 0.2 ^{a2}
S9		9.0 ± 0.1 ^{a4}	8.6 ± 0.1 ^{b3}	8.4 ± 0.1 ^{c2}	8.5 ± 0.1 ^{c23}	7.9 ± 0.00 ^{c1}
Control		9.1 ± 0.2 ^{a12}	9.6 ± 0.3 ^{a2}	9.5 ± 0.1 ^{ab2}	9.1 ± 0.2 ^{b12}	8.7 ± 0.3 ^{b1}
Blank		4.3 ± 0.1 ^{b3}	5.2 ± 0.1 ^{b4}	4.2 ± 0.1 ^{d3}	3.5 ± 0.2 ^{d2}	2.1 ± 0.4 ^{d1}
b^*		S3	10.1 ± 0.5 ^{a1}	9.9 ± 0.1 ^{b12}	9.8 ± 0.3 ^{b12}	9.8 ± 0.1 ^{b12}
	S6	10.1 ± 0.1 ^{a1}	9.8 ± 0.1 ^{b1}	10.0 ± 0.1 ^{b1}	9.6 ± 0.3 ^{bc1}	9.6 ± 0.5 ^{b1}
	S9	10.7 ± 0.4 ^{ab1}	9.6 ± 0.9 ^{b12}	9.9 ± 0.1 ^{b12}	9.3 ± 0.5 ^{c2}	8.7 ± 0.1 ^{c3}
	Control	10.9 ± 0.1 ^{b1}	10.1 ± 0.1 ^{b2}	9.1 ± 0.1 ^{c3}	9.6 ± 0.0 ^{bc23}	10.1 ± 0.4 ^{ab2}
	Blank	11.8 ± 0.1 ^{a12}	11.5 ± 0.1 ^{a2}	11.9 ± 0.2 ^{a1}	11.2 ± 0.1 ^{a3}	10.7 ± 0.2 ^{a4}

^a In each column, means identified with different letters are significantly different ($P < 0.05$). In each row, means identified with different numbers are significantly different ($P < 0.05$). ^b Sample symbols are defined in Table 1.

**Table 7.** Sensory evaluation of the selected sausage samples (3 replicates).^a

Sample ^b	Color	Flavor		Overall acceptability
		Odor	Taste	
S3	6.5±0.6 ^{ab}	8.2±0.6 ^a	6.4±0.7 ^a	7.3±1 ^a
S6	6.6±0.6 ^{ab}	8.2±0.6 ^a	6.3±0.8 ^{ab}	7.2±0.7 ^a
S9	6.2±0.8 ^b	8.3±0.7 ^a	5.9±0.8 ^b	6.5±1 ^b
Control	6.6±0.7 ^a	8.1±0.9 ^a	5.8±0.8 ^b	7.1±1.3 ^{ab}
Blank	3.8±0.7 ^c	7.5±0.2 ^b	4.3±0.9 ^c	5.3±1 ^c

^a In each column, means identified with different letters are significantly different (P< 0.05).

^b Sample symbols are defined in Table 1.

the products (Lynch and Faustman, 2000). Slight increase in the a^* value was observed for S6 during the storage, indicating a color change from red to brown possibly due to the formation of metmyoglobin (Hunt *et al.*,1999). Under a reducing condition, a dark red color is observed due to the formation of nitric oxide myoglobin (Schmidt, 1986). Yellowness (b^* value) is another color attribute considered in the current study. On day 2, S3 and S6 indicated slightly lower yellowness when compared to the control sample. Except for S6, all samples of this study lost their yellowness during the 30 days of storage (Table 6). In general, the results of the instrumental yellow color (b^*) measurements followed the TBARS values. Lauritzen and Martinsen (1999) reported that the yellowness was correlated with lipid oxidation in cod fillets during the salting process, with increases in lipid oxidation raising yellow pigment formation.

Yu *et al.* (28) also reported that lipid oxidation correlated with an increase in b^* values in cooked turkey products during refrigerated storage. Yellow pigment in the meat product is produced by the non-enzymatic browning reactions occurring between lipid oxidation products and amino groups of the proteins.

Treatments Effect on the Sensory Attributes of the Sausages

The results for the sensory evaluation of the sausage samples from the current study are shown in Table 7. The taste score given for S3 sample was lower than that of

the control. No significant differences were found in flavor of S6, S9, and the control samples (Table 7). Scores given for the odor of the samples S3, S6, S9, and the control were not different. Overall score for the flavor of blank sample was lower than those of the other samples. Considering the overall acceptability of the samples, S3, S6, and the control received higher scores than S9 and blank.

CONCLUSIONS

This study showed that high level of barberry extract (90 mg kg⁻¹) with a low level of nitrite (30 or 60 mg kg⁻¹) can be used effectively to extend the shelf-life of cooked sausages if stored under refrigerated conditions (4°C). Barberry extract resulted in an increase in the antioxidant activities of the samples suggesting that partial replacement of nitrite with this extract can result in a healthier product, potentially reducing the risk of cancer due to the reduced nitrosamine formation in the sausage products. Samples with 90 mg kg⁻¹ barberry extract and the lowest level of nitrite (30 and 60 mg kg⁻¹) were granted the highest score in the sensory evaluation of the samples.

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REFERENCES

1. Akbulut, M., Çalışır, S., Marakoğlu, T. and Çoklar, H. 2009. Some Physicomechanical and Nutritional Properties of Barberry (*Berberis vulgaris* L.) Fruits. *J. Food Proc. Eng.*, **32**: 497- 511.
2. Al-Shuibi, A. M. and Al-Abdullah, B. M. 2002. Substitution of Nitrite by Sorbate and the Effect on Properties of Mortadella. *Meat Sci.*, **62**: 473 – 478.
3. AOAC. 2002a. Fat (Crude) or Ether Extract in Meat: 960.39. In: “*Official Methods of Analysis of AOAC International*”, (Ed.): Horwitz, W. 17th Edition, Pub. Suite 500, Maryland, USA.
4. AOAC. 2002b. Crude Protein in Meat: 928.08. In: “*Official Methods of Analysis of AOAC International*”, (Ed.): Horwitz, W. 17th Edition, Pub. By Association of Official Methods of Analysis Chemists, Suite 500, Maryland, USA.
5. AOAC. 2002c. Determination of Moisture Content: 950.46. In: “*Official Methods of Analysis of AOAC International*”, (Ed.): Horwitz, W. 17th Edition, Pub. Suite 500, Maryland, USA.
6. AOAC. 2002d. Ash Content of Meat: 920.153. In: “*Official Methods of Analysis of AOAC International*”, (Ed.): Horwitz, W. 17th Edition, Suite 500, Maryland, USA.
7. Baydar, H., Sagdiç, O., Gülcan, O. and Karadogan, T. 2004. Antibacterial Activity and Composition of Essential Oils from Origanum, Thymbra, and Satureja Species with Commercial Importance in Turkey. *Food Control*, **15**: 169 - 172.
8. Bozkurt, H. 2006. Utilization of Natural Antioxidants: Green Tea Extract and *Thymbraspicata* oil in Turkish Dry-fermented Sausage. *Meat Sci.*, **73**: 442 - 450.
9. Brannan, R. G. 2009. Effect of Grape Seed Extract on Descriptive Sensory Analysis of Ground Chicken during Refrigerated Storage. *Meat Sci.*, **81**: 589 - 595.
10. Cammack, R., Joannou, C. L., Cui, X. Y., Martinez, C. T., Maraj, S. R. B. and Martin, N. H. 1999. Nitrite and Nitrosyl Compounds in Food Preservation. *Biochim. Biophys. Acta*, **1411**: 475- 488.
11. Cassens, R. G. 1997. Residual Nitrite in Cured Meat. *Food Technol.*, **51**: 53-55.
12. Coutinho de Oliveira, T. L., de Carvalho, S. M., de Araújo Soares, R., Andrade, M. A., das Graças Cardoso, M., Ramos, M. E. and Piccoli, R. H. 2012. Antioxidant Effects of *Satureja montana* L. Essential Oil on TBARS and Color of Mortadella-type Sausages Formulated with Different Levels of Sodium Nitrite. *LWT-Food Sci. Technol.*, **45**: 204–212.
13. DeveliIsikh, N. D. and Yilmaz, I. 2011. Some Physical Properties of Sun-dried Berberis Fruit (*Berberis crataegina*). *J. Food Sci. Technol.*, **51**(1): 104–110.
14. Dorman, H. J. D., Peltoketo, A., Hiltunen, R. and Tikkanen, M. J. 2003. Characterization of the Antioxidant Properties of De-odorized Aqueous Extracts from Selected *Lamiaceae* Herbs. *Food Chem.*, **83**: 255 – 262.
15. Dolati, M., Rezaei, K., Piravi Vanak, Z. and Movahed, S. 2015. Study of the Effects of Essential Oils of Cumin, Savory and Cardamom as Natural Antioxidants on the Flavor and Oxidative Stability of Soybean Oil during the Storage. *J. Essent. Oil Bearing Plants.*, **19**(1): 176-184
16. Fernandez, J., Perez-Álvarez, J. A. and Fernandez-Lopez, J. A. 1997. Thiobarbituric Acid Test for Monitoring Lipid Oxidation in Meat. *Food Chem.*, **59**: 345–353.
17. Fernández-Gines, J. M., Fernández-López, J., Sayas-Barbera, E., Sendra, E. and Perez-Alvarez, J. A. 2003. Effect of Storage Conditions on Quality Characteristics of Bologna Sausages Made with Citrus Fiber. *J. Food Sci.*, **68**(2): 710–715.
18. Fernández-Lo´pez, J., Fernández-Gine´s, J. M., Aleson-Carbonell, L., Sendra, E., Sayas-Barbera´, E. and Pe´rez-A´lvarez, J. A. 2004. Application of Functional Citrus By-products to Meat Products. *Trend. Food Sci. Technol.*, **15**, 176–185.



19. Fernández-López, J., Viuda-Martos, M., Sendra, E., Sayas-Barberá, E., Navarro, C. and Pérez-Alvarez, J. A. 2007. Orange Fibre as Potential Functional Ingredient for Dry Cured Sausages. *Eur. Food Technol.*, **226**(1): 1–6.
20. Fernández-López, J., Senda-Nadal, E., Navarro, C., Sayas-Barbera, E., Viuda-Martos, M. and Perez-Alvarez, J. A. 2009. Storage Stability of a High Dietary Fiber Powder from Orange by-Products. *Int. J. Food Sci. Technol.*, **44**(4): 748-756.
21. Gotterup, J., Olsen, K., Knochel, S., Tjener, K., Stahnke, L. H. and Moller, J. K. S. 2008. Color Formation in Fermented Sausages by Meat-associated Staphylococci with Different Nitrite- and Nitrate-reductase Activities. *Meat Sci.*, **78**: 492-501.
22. Gulsoy, S. and Ozkan, K. 2011. Mineral Elements, Phenolics and Organic Acids of Leaves and Fruits from *Berberis crataegina* DC. *Asian J. Chem.*, **23**: 3071–3074
23. Hernández-Hernández, E., Ponce-Alquicira, E., Jaramillo-Flores, M. E. and Legarreta, G. 2009. Antioxidant Effect of Rosemary (*Rosmarinus officinalis* L.) and Oregano (*Origanum vulgare* L.) Extracts on TBARS and Color of Model Raw Pork Batters. *Meat Sci.*, **81**: 410 - 417.
24. Hunt, M. C., Sørheim, O. and Slinde, E. 1999. Color and Heat Denaturation of Myoglobin Forms in Ground Beef. *J. Food Sci.*, **64**: 847-851.
25. Hustad, G. O., Cerveny, J. H., Trenk, H., Deibel, R. H., Kautter, D. A., Fazio, T., Johnston, R. W. and Kolari. O. E. 1973. Effect of Sodium Nitrite and Sodium Nitrate on Botulinal Toxin Production and Nitrosamine Formation in Wieners. *Appl. Microb.*, **26**: 22- 6.
26. Imanshahidi, M. and Hosseinzadeh, H. 2008. Pharmacological and Therapeutic Effects of *Berberis vulgaris* and Its Active Constituent Berberine. *Phytoth. Res.*, **22**: 999 –1012
27. ISIRI. 2010. *Sausages: Specification and Test Methods*. ISIRI No 2303, Institute of Standards and Industrial Research of Iran.
28. ISO. 1975. *Meat and Meat Products: Determination of Nitrite Content*. ISO No 2918/75, 09-01, International Organization for Standardization, Switzerland.
29. ISO. 2003. *Microbiology of Food and Animal Feeding Stuffs Horizontal Method for the Enumeration of Microorganisms: Colony-count Technique at 30°C*. ISO 4833:2003(E), International Organization for Standardization, Switzerland.
30. Karl-Otto, H. 2008. The Use and Control of Nitrate and Nitrite for the Processing of Meat Products. *Meat Sci.*, **78**: 68–76.
31. Kim, Y. J., Jin, S. K., Park, W. Y., Kim, B. W., Joo, S. T. and Yang, H. S. 2010. The Effect of Garlic of Onion Marinade on the Lipid Oxidation and Meat Quality of Pork during Cold Storage. *J. Food Qual.*, **33**: 171–185.
32. Konczak, I. and Zhang, W. 2004. Anthocyanin's-more than Nature's Colors. *J. Biomed. Biotechnol.*, **5**: 239 – 240.
33. Lau, D. W. and King, A. J. 2003. Pre-and Post-mortem Use of Grape Seed Extract in Dark Poultry Meat to Inhibit Development of Thiobarbituric Acid Reactive Substances. *J. Agr. Food Chem.*, **51**(6): 1602–1607.
34. Lauritzsen, K. and Martinsen, G. 1999. Copper induced lipid oxidation during salting of cod (*Gadus morhua*). *J. Food Lipids*, **6**: 299-315
35. Li, Y., Du, Y. and Zou, C. 2009. Effects of pH on Antioxidant and Antimicrobial Properties of Tea Saponins. *Eur. Food Res. Technol.*, **228**: 1023-1028
36. Lücke, F. K. 2000. Use of Nitrite and Nitrate in the Manufacture of Meat Products. *Fleischwirtschaft Int.*, **4**: 38-41.
37. Lynch, M. P. and Faustman, C. 2000. Effect of Aldehyde Lipid Oxidation Products on Myoglobin. *J. Agri. Food Chem.*, **48**(3): 600 – 604.
38. Maaroufi S. H., Rezaei, K. Raftaniamiri, Z. and Mirzaei, F. 2015. Evaluating the Effects of Herbal Essences from Spearmint and Wild Thyme on the Quality of Camel's Milk. *Int. J. Food Sci. Technol.*, In press.
39. Mazidi. S., Rezaei, K., Golmakani, M. T., Sharifan, A., Rezazadeh, S. H. 2012. Antioxidant Activity of Essential Oil from Black Zira (*Bunium persicum* Boiss.) Obtained by Microwave-Assisted Hydrodistillation. *J. Agr. Sci. Tech.*, **14**: 1013-1022.
40. Melton, S. L. 1983. Methodology for Following Lipid Oxidation in Muscle Foods. *Food Technol.*, **38**: 105 - 111.
41. Moerck, K. E. and Ball, H. R. 1974. Lipid Autoxidation in Mechanically Deboned Chicken Meat. *J. Food Sci.*, **39**: 876 - 879.
42. Mollaei, A., Rezaei, K., Khodayian, F. and Razavi, H. 2010. Segregate Functional

- Compounds from Barberry's Fruit Extracts. *Iran. Nation. Conf. Function. Food.*, 341-350.
43. Mousavinejad, G., Rezaei, K. and Khodaeian, F. 2015. Reducing Acrylamide in Fried Potato Pancake Using Baker's Yeast, Lactobacilli and Microalgae. *Qual. Assur. Safe. Crop. Food.*, **7** (5): pp. 779-787.
 44. Nychas, G. J. E., Drosinos, E. H. and Board, R. G. 1998. *Chemical Changes in Stored Meat: the Microbiology of Meat and Poultry*. Blackie Academic and Professional, London, PP. 288-326.
 45. Ockerman, H. W. 1976. *Quality Control of Postmortem Muscle and Tissue*. PhD. Thesis, Ohio State University, Columbus, OH.
 46. Parichehr, H. and Golkho, S. H. 2009. Using HPLC to Determination the Composition and Antioxidant Activity of *Berberis vulgaris*. *Eur. J. Sci. Res.*, **29**: 47-54
 47. Pfalzgraf, A., Frigg, M. and Stinhart, H. 1995. Alpha-tocopherol Contents and Lipid Oxidation in Pork Muscle and Adipose Tissue during Storage. *J. Agri. Food Chem.*, **43**: 1339 - 1342.
 48. Perez-Rodriguez, M. L., Bosch-Bosch, N. and Garcia-Mata, M. 1996. Monitoring Nitrite and Nitrate Residues in Frankfurters during Processing and Storage. *Meat Sci.*, **44**: 65-73.
 49. Pourazrang, H., Moazzami, A. A. and Fazly Bazzaz, B. S. 2002. Inhibition of Mutagenic N-nitroso Compound Formation in Sausage Samples Using L-ascorbic Acid and α -tocopherol. *Meat Sci.*, **62**: 479-483.
 50. Rywotycki, R. 2002. The Effect of Selected Functional Additives and Heat Treatment on Nitrosamine Content in Pasteurized Pork Ham. *Meat Sci.*, **60**: 335-339.
 51. Smith, J. L. and Alford, J. A. 1968. Action of Microorganisms on the Peroxides and Carbonyls of Rancid Fat. *J. Food Sci.*, **33**: 93-97.
 52. Schmidt, G. R. 1986. *Processing and Fabrication. Muscle as Food*. Academic Press, New York, USA, PP. 201-239.
 53. Sallam, Kh. I., Ishioroshi, M. and Samejima, K. 2004. Antioxidant and Antimicrobial Effects of Garlic in Chicken Sausage. *LWT-Food Sci. Technol.*, **37**: 849-855.
 54. Terns, M. J., Milkowski, A. L., Rankin, S. A. and Sindelar, J. J. 2011. Determining the Impact of Varying Levels of Cherry Powder and Starter Culture on Quality and Sensory Attributes of Indirectly Cured, Emulsified Cooked Sausages", *Meat Sci.*, **88**: 311-318
 55. Viuda-Martos, M., Ruiz-Navajas, Y., Fernández-López, J. and Pérez-Alvarez, J. A. 2009. Effect of Adding Citrus Waste Water, Thyme and Oregano Essential Oil on the Chemical, Physical and Sensory Characteristics of a Bologna Sausage. *Innov. Food Sci. Emerg. Technol.*, **10**: 655-660.
 56. Viuda-Martos, M., Ruiz-Navajas, Y., Fernández-López, J. and Pérez-Alvarez, J. A. 2010. Effect of Adding Citrus Fiber Washing Water and Rosemary Essential Oil on the Quality Characteristics of a Bologna Sausage. *LWT-Food Sci. Technol.*, **43**: 958 - 963.
 57. Wallace T.C. and Giusti, M. M. 2008. Determination of Color, Pigment, and Phenolic Stability in Yogurt Systems Colored with Non-acylated Znthocyanins from *Berberis boliviana* as Compared to Other Natural/Synthetic Colorants. *J. Food Sci.*, **73**: 241-248
 58. Yanishlieva, N. V., Marinova, E. and Pokorny, J. 2006. Natural Antioxidants from Herbs and Spices. *Eur. J. Lipid Sci. Technol.*, **108**: 776 - 793.
 59. Yetim, H., Kayacier, A., Kesmen, Z. and Sagdic, O. 2006. The Effects of Nitrite on the Survival of *Clostridium sporogenes* and the Autoxidation Properties of the Kavurma. *Meat Sci.*, **72**: 206-210.
 60. Yu, L.L., Scanlin, L. Wilson, J., Schimdt, G. 2006 Rosemary Extracts as Inhibitors of Lipid Oxidation and Color Change in Cooked Turkey Products during Refrigerated Storage, *J. Food Sci.*, **67**(2): 582-585
 61. Zanardi, E., Dazzi, G., Madarena, G. and Chizzolini, R. 2002. Comparative Study on Nitrite and Nitrate Ions Determination. *Ann. Fac. Med. Vet. Parma*, **22**: 70-86.



تأثیر مشترک عصاره زرشک سیاه و نیتريت بر روی کیفیت و زمان ماندگاری سوسیس پخته در طی نگهداری در دمای یخچال

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چکیده

اثر مشترک ترکیب عصاره زرشک سیاه (*Berberis crataegina*) و نیتريت سدیم روی کیفیت و زمان ماندگاری سوسیس های پخته شده مورد بررسی قرار گرفت. غلظت های متفاوتی از این عصاره در ترکیب با نیتريت به فرمولاسیون سوسیس افزوده شد. شمارش کل میکروبی، pH، آنالیز تقریبی، سطح نیتريت باقیمانده، اکسیداسیون لیپید، رنگ و داده های حسی در برابر نمونه شاهد و کنترل در طی نگهداری در مدت ۳۰ روز در دمای ۴ °C مورد مطالعه قرار گرفت. کاهش تدریجی سطح نیتريت در طی مدت زمان نگهداری در همه نمونه های مورد مطالعه مشاهده شد. نمونه هایی که عصاره زرشک سیاه در آنها به کار رفته بود در مقایسه با نمونه سوسیس شاهد رنگ قرمز مشابه با میزان روشنی کمتری داشتند. ارزیابی حسی نمونه ها نتایج مشابه با نمونه های کنترل را نشان داد. برتری بالقوه ای در جایگزین کردن این عصاره با بخشی از نیتريت سدیم در محصولات گوشتی فرآوری شده مشاهده شد.