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FUNCTIONAL APPLICATION OF BARBERRY EXTRACT IN PASTIRMA: INHIBITION OF NITROSAMINES FORMATION AND OXIDATIVE CHANGES DURING REFRIGERATED STORAGE

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I. INTRODUCTION

In recent years, oxidative and nitrosative stress in processed meat products has posed significant health risks. In particular, cured meat products undergo lipid and protein oxidation, as well as nitrosation reactions, during the curing and cooking processes [1]. The use of nitrite salts can lead to the formation of nitrosamines, which may have carcinogenic effects [2]. However, natural antioxidant compounds, such as red barberry (*Berberis vulgaris*) extract, have the potential to enhance the quality of meat products by inhibiting oxidation and nitrosation processes [3]. Additionally, modern techniques like vacuum impregnation can promote the homogeneous distribution of these bioactive compounds in meat products, thereby reducing the negative effects of these reactions [4]. This study examines the impact of varying concentrations of red barberry extract on pastirma (Turkish dry-cured meat product) formulation during a 3-month storage period.

II. MATERIALS AND METHODS

Preparation of barberry extract and pastirma

The dried barberry samples were milled and subjected to ultrasonic-assisted extraction with ethanol (33 mL/g) for 12.44 minutes at 20 kHz and 36% amplitude. After extraction, the mixture was filtered, and ethanol was removed using a rotary evaporator at <55°C. The shaped beef blocks (1.5-2 kg) were cured in a solution containing 15% NaCl and 0.015 g $NaNO_2$, and barberry extract at concentrations of 0 ppm (P0), 200 ppm (P2), 300 ppm (P3), 400 ppm (P4) by vacuum curing assisted with US. Pastirma production followed the methods reported by Aksu and Kaya [5] and Akköse et al. [6]. Thiobarbituric acid (TBARS) values were assessed following the method of Witte et al. [7]. The total carbonyl content in the samples was evaluated using the method of Armenteros et al. [8]. Nitrosamine concentrations were determined using gas chromatography coupled with mass spectrometry (GC-MS) [9]. N-Nitrosodimethylamine (NDMA), N-Nitrosodiethylamine (NDEA),N-Nitrosopiperidine (NPIP), and N-Nitrosopyrrolidine (NPYR) were detected in samples. Data was analyzed using one-way ANOVA with SPSS software version 21, and Duncan's Multiple Range Test was applied to compare the means. A significance level of $P<0.05$ was considered for all statistical evaluations.

III. RESULTS AND DISCUSSION

The effects of barberry extract addition at different concentrations on nitrosamine formation, lipid oxidation (TBARS), and protein oxidation (carbonyl content) in pastirma during 3 months of storage are presented in Table 1 and Figure 1. Lipid oxidation, as assessed by TBARS (Figure 1), increased progressively in all groups with storage. However, P4 exhibited significantly lower TBARS values at each storage point, with the most notable difference observed at month 3 (P4: 3.5 mg MDA/kg vs. P0: 4.8 mg MDA/kg). These results suggest that barberry extract, particularly at 400 ppm, effectively inhibited lipid oxidation in pastirma samples. Similarly, carbonyl content, an indicator of protein oxidation, increased significantly with storage ($P<0.05$), with the highest values in P0 and the lowest in P4. At the end of storage, P4 had the lowest carbonyl content (5.81 nmol/mg protein), while P0 reached 6.39 nmol/mg protein, confirming the antioxidative potential of barberry extract.

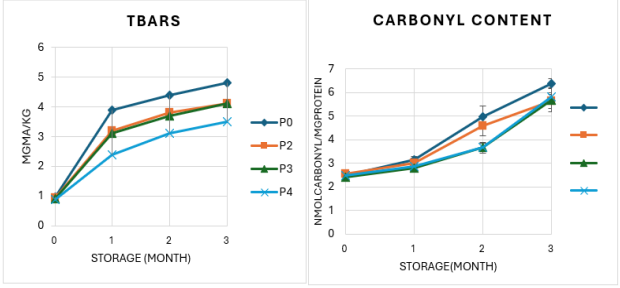


Figure 1. TBARS and Carbonyl content of pastirma

Nitrosamine levels varied significantly ($P<0.05$) depending on both the concentration of barberry extract and the duration of storage. At month 0, P4 exhibited significantly lower levels of NDMA and NDEA compared to P0,

indicating the inhibitory effect of barberry extract on nitrosamine formation. Similarly, NPIP and NPYR contents in P4 were significantly lower than in the control group. These dependent reductions were consistent throughout the storage period. At month 3, P4 maintained significantly lower NDMA and NPYR levels compared to P0, confirming the long-term protective effect of the highest barberry concentration. All nitrosamines, particularly NDMA and NDEA, increased in P0 over time ($P<0.05$). However, P4 showed the least increase, suggesting a potential role of the extract in mitigating nitrosamine formation during extended storage.

Table 1. Nitrosamine concentration of pastirma

Treatment	Storage (month)	NDMA (ppb)	NDEA (ppb)	NPIP (ppb)	NPYR (ppb)
P0	0	5.03 ± 0.30 ^{a,z}	3.00 ± 0.20 ^{a,z}	2.07 ± 0.15 ^{a,z}	3.10 ± 0.20 ^{a,z}
P2		4.02 ± 0.25 ^{b,z}	2.53 ± 0.48 ^{a,z}	1.56 ± 0.12 ^{b,z}	2.57 ± 0.20 ^{b,z}
P3		3.51 ± 0.20 ^{c,z}	2.03 ± 0.15 ^{b,z}	1.22 ± 0.10 ^{c,z}	1.81 ± 0.12 ^{c,z}
P4		2.58 ± 0.15 ^{d,z}	1.53 ± 0.10 ^{c,z}	1.03 ± 0.07 ^{d,z}	1.25 ± 0.08 ^{d,z}
P0	1	5.52 ± 0.32 ^{a,y}	3.10 ± 0.22 ^{a,y}	2.23 ± 0.18 ^{a,y}	3.32 ± 0.22 ^{a,y}
P2		4.56 ± 0.18 ^{b,y}	2.76 ± 0.20 ^{b,y}	1.77 ± 0.15 ^{b,y}	2.75 ± 0.22 ^{b,y}
P3		4.05 ± 0.45 ^{b,y}	2.24 ± 0.17 ^{c,y}	1.56 ± 0.22 ^{b,y}	2.04 ± 0.15 ^{c,y}
P4		3.04 ± 0.20 ^{c,y}	1.87 ± 0.12 ^{d,y}	1.21 ± 0.08 ^{c,y}	1.52 ± 0.10 ^{d,y}
P0	2	6.01 ± 0.35 ^{a,x}	3.55 ± 0.25 ^{a,x}	2.56 ± 0.20 ^{a,x}	3.55 ± 0.25 ^{a,x}
P2		5.04 ± 0.30 ^{b,x}	2.95 ± 0.22 ^{b,x}	1.94 ± 0.18 ^{b,x}	3.01 ± 0.25 ^{b,x}
P3		4.54 ± 0.28 ^{c,x}	2.44 ± 0.20 ^{c,x}	1.87 ± 0.15 ^{c,x}	2.21 ± 0.18 ^{c,x}
P4		3.51 ± 0.22 ^{d,x}	2.06 ± 0.15 ^{d,x}	1.57 ± 0.10 ^{d,x}	1.85 ± 0.12 ^{d,x}
P0	3	6.54 ± 0.38 ^{a,t}	3.83 ± 0.28 ^{a,t}	2.83 ± 0.22 ^{a,t}	3.86 ± 0.28 ^{a,t}
P2		5.52 ± 0.32 ^{b,t}	3.11 ± 0.25 ^{b,t}	2.13 ± 0.20 ^{b,t}	3.23 ± 0.28 ^{b,t}
P3		5.06 ± 0.30 ^{c,t}	2.66 ± 0.22 ^{c,t}	2.05 ± 0.18 ^{c,t}	2.54 ± 0.20 ^{c,t}
P4		4.05 ± 0.25 ^{d,t}	2.23 ± 0.18 ^{d,t}	1.82 ± 0.12 ^{d,t}	2.06 ± 0.15 ^{d,t}

$^{a-d}$Different letters indicate a significant difference between groups ($P < 0.05$). $^{x-t}$Different letters indicate a significant difference during storage ($P < 0.05$).P0:pastırma impregnated with 0 ppm BE; P2:pastırma impregnated with 200 ppm BE;P3:pastırma impregnated with 300 ppm BE, P4:pastırma impregnated with 400 ppm BE

IV. CONCLUSION

Overall, the incorporation of barberry extract, especially at 400 ppm, significantly reduced nitrosamine formation and oxidative changes in pastirma during refrigerated storage, offering a promising approach to enhance the safety and shelf life of cured meat products. This highlights the potential of natural plant-based additives to enhance product safety without compromising traditional curing methods. Future research may focus on mechanism-based studies, the use of different nitrite/nitrate sources, and the combined use of complementary natural compounds to further improve product quality.

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